THE INSTITUTE OF PHYSICS BULLETIN

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Appointments Vacant

The inclusion of particulars of a vacancy must not be taken to imply that the Institute and Society necessarily approves of the terms offered or that might be offered. Candidates should satisfy themselves that these are satisfactory, and they may always refer to the Institute and Society for advice.

MONASH UNIVERSITY
CLAYTON, VICTORIA, AUSTRALIA
SENIOR LECTURESHIPS AND LECTURESHIPS IN MATHEMATICS

Applications are invited for appointment to the above mentioned positions. The Department of Mathematics will be concerned in 1961 with teaching Mathematics at first year level to students in the Faculties of Arts, Science and Engineering and with postgraduate students. The Interim Council has recently appointed to the Chair of Mathematics Dr. K. C. Westfold of the University of Sydney whose main interests lie in theoretical radio astronomy and magnetohydrodynamics. It is the University's intention to establish and maintain conditions favourable to the prosecution of research by all academic staff members. Salary scales: Senior Lecturer £A2,480 × £100 – £2,950; Lecturer £A1,660 × £100 – £2,360; with provision for superannuation on the F.S.S.U. basis. The initial salary will be fixed within the scale in relation to the successful candidate's qualifications and experience. General conditions of appointment (including details of the provisions made for travelling expenses, housing, study leave, tenure, etc.) may be had from the Registrar of the University, P.O. Box 92, Clayton, Victoria, Australia, or from the Secretary, Association of Universities of the British Commonwealth, 36 Gordon Square, London, W.C.1. Applications, in duplicate, and giving the information listed in the general conditions of appointment, should be lodged with the Registrar of the University not later than December 5 1960. An applicant resident elsewhere than in Australia or New Zealand should also send one copy of his application to the Secretary, Association of Universities of the British Commonwealth, 36 Gordon Square, London, W.C.1.

UNIVERSITY OF SYDNEY
LECTURESHIP AND SENIOR LECTURESHIP IN APPLIED MATHEMATICS

Applications are invited for the above-mentioned positions. Salary for a Lecturer is within the range £A1,730 × £105 – £2,435 per annum; for a Senior Lecturer within the range £A2,550 × £95 – £3,000 per annum and will be subject to deductions under the State Superannuation Act. In addition, in each case, cost of living adjustments (at present £A13 p.a.) will be paid. The commencing salary will be fixed according to the qualifications and experience of the successful applicant. Under the Staff Members' Housing Scheme, in cases approved by the University and its Bankers, married men may be assisted by loans to purchase a house. Further particulars and information as to the method of application may be obtained from the Secretary, Association of Universities of the British Commonwealth, 36 Gordon Square, London, W.C.1. Applications close in Australia and London on December 31, 1960.

UNIVERSITY OF QUEENSLAND
LECTURER IN RADIATION PHYSICS AND RADIATION SAFETY OFFICER

Applications are invited for the above-mentioned position. Applicants should hold a degree in Science with Honours in Physics and some experience in the use of ionizing radiation. Preference will be given to applicants with experience in using radioactive substances and in the principles of hospital or health physics; knowledge of counter electronics is an advantage. The appointee will be required to assist all University departments using X-rays or radioactive substances in teaching or in research, and to co-ordinate this work with the activities of the Radiation Physics group already established in hospitals. Opportunities exist for research. Salary range £A1,830–£A70–£A2,330. The successful applicant will enjoy the privileges of superannuation, study leave, travel grants and other benefits available to the academic staff. Further particulars and application forms are obtainable from the Secretary, Association of Universities of the British Commonwealth, 36 Gordon Square, London, W.C.1. Applications close, in Australia and London, on November 19, 1960, or within two weeks.

THE UNIVERSITY OF SHEFFIELD

Applications are invited from Physicists with appropriate qualifications and experience for a post of HEALTH PHYSICIST in the University, to begin duties on January 1, 1961, or as soon as possible thereafter. The post will carry with it the status of Lecturer. Initial salary according to qualifications and experience on the scale £1,050 × £50–£1,400 × £75–£1,850, with F.S.S.U. provision and family allowance. A grant towards removal expenses will be made. Throughout the various University departments in the Faculties of Pure Science, Medicine, Engineering and Metallurgy an increasing amount of work is being done involving the use of radioactive materials, X-rays and other sources of ionizing radiation. The University has adopted a Code of Practice in respect of this work, the implementation of which requires the appointment of an adequately qualified person to advise on and, under the appropriate University Committee, to control all arrangements for the protection of those concerned, either directly or indirectly, and to give such instruction in radiation physics as may be required by these duties or arranged by the Faculties of Pure Science or Medicine. The Sheffield Regional Hospital Board has agreed that the Health Physicist should be offered bench space in the Physics Department of the Radiotherapy Centre in Sheffield and afforded full facilities for research work in association with their Chief Physicist and his colleagues. Further particulars may be obtained from the Registrar, The University, Sheffield 10, to whom applications (8 copies) should be sent by November 26, 1960.

AUSTRALIA
THE UNIVERSITY OF NEW SOUTH WALES
SENIOR LECTURER / LECTURER IN PHYSICS

The University invites applications for appointment to positions of Senior Lecturer or Lecturer in the School of Physics. Salary: Senior Lecturer £A2,563 range £A3,013 per annum. Lecturer £A1,743 range £A2,448 per annum. Commencing salary according to qualifications and experience. Applicants must possess a degree with honours and preferably a higher degree in physics, or equivalent qualifications. Research experience in theoretical or experimental solid-state physics is desirable. Subject to passing a medical examination, the appointee will be eligible to contribute to the State Superannuation Fund. First class ship fare to Sydney of appointee and his family will be paid. Four copies of applications, together with the names of two referees, should be lodged with the Agent General for New South Wales, 56 Strand, London, W.C.2, and a copy forwarded by airmail in an envelope marked "University Appointment" to the Bursar, The University of New South Wales, Box 1, Post Office, Kensington, New South Wales, Australia, before January 31, 1961.

ASSISTANT PHYSICIST

Applications are invited for the above post, which is on the staff of the Area Chief Chemist located in Birmingham. The duties involve interesting work on instrumentation in a modern laboratory and candidates should possess at least a Higher National Certificate in Physics or equivalent qualification. The commencing salary will be not less than £900 per annum. Excellent sickness, pension, and holiday schemes. Applications, giving details of age, experience and qualifications, should be addressed to the Industrial Relations Officer, West Midlands Gas Board, 6 Augustus Road, Edgbaston, Birmingham, 15.

UNIVERSITY OF QUEENSLAND

Applications are invited for the following positions in the Department of Physics:—(*a*) LECTURER IN THEORETICAL PHYSICS; LECTURER IN PHYSICS. Applicants should have an Honours Degree in Physics or its equivalent. Previous teaching experience is desirable though not essential. The Lecturer in Theoretical Physics will lecture mainly to third year and Honours students. The salary range for Lecturer is £A1,830 × £70 – £2,330. The successful applicants will enjoy the privileges of superannuation, study leave, travel grants and other benefits available to the academic staff. Further particulars and information as to the method of application may be obtained from the Secretary, Association of Universities of the British Commonwealth, 36 Gordon Square, London, W.C.1. Applications close in Australia and London on November 30, 1960.

IMPERIAL COLLEGE OF SCIENCE AND TECHNOLOGY

PHYSICS DEPARTMENT

Applications are invited for the following posts in the photo-electronics section:—

LECTURER: Salary in range £1,050 × £50 to £1,400 × £75 to £1,550 (bar) × £75 to £1,850 per annum, plus £60 per annum London Allowance and Family Allowance of £50 per child per annum. F.S.S.U. membership.

Duties include teaching General Physics and special Advanced Course, research in application of photo-electronics to nuclear physics, astronomy, space research, etc.

RESEARCH ASSISTANT (Academic) to carry out research in the fields of vacuum physics and photo-electronics. A good degree essential and some research experience preferable. Salary in range £700 to £1,100 per annum, depending upon qualifications. F.S.S.U. membership.

SENIOR EXPERIMENTAL OFFICER: Salary in range £1,050 × £50 to £1,250 (bar) × £50 to £1,500 per annum. Superannuation Scheme. A degree or equivalent qualification necessary, together with wide technical experience, preferably in fields of vacuum, photo-electric, and electronic techniques. Required to give active and constructive support to research programme in these fields.

Apply, with full personal and academic details and names of two referees, to:

Professor J. D. McGee,
Physics Department,
Imperial College of Science and Technology,
London, S.W.7.

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Head of Technical Development,
Pilkington Brothers Limited,
St. Helens,
Lancashire.

COMMONWEALTH OF AUSTRALIA

DEPARTMENT OF SUPPLY

PHYSICS OF PHOTOCONDUCTION

Applications are invited for the following position at the Defence Standards Laboratories, Finsbury, Adelaide, South Australia:—

Position and Salary: HIGHER SCIENTIFIC OFFICER—£2,005/£2,265 (Australian currency)

Duties: The laboratories have developed new and commercially important processes in the field of xerography. The successful applicant will undertake basic studies relating to the effects of light, X and gamma radiation on photoconductive materials, and the physics of electrophotography. This work is designed to extend the applicability of xerography to fields where it cannot as yet be satisfactorily employed, but where it promises to be a valuable technique in medical and scientific work.

Qualifications: Honours degree, and research experience.

Conditions: Under specified conditions, first class air/sea transport for the appointee and dependents (wife and dependant children) will be provided by the Commonwealth. Salary payable from date of embarkation. If desired by the successful candidate consideration may be given to entering into an agreement for a three (3) or five (5) year contract of employment in Australia. In this case the Commonwealth will bear the cost of return fares; together with the cost of removing the successful applicant's furniture and effects up to a maximum cost of £500 (Australian), £250 each way.

Applications: Forms obtainable from Senior Representative (AV.79/10), Department of Supply, Australia House, Strand, London, W.C.2, with whom applications should be lodged by November 30, 1960. Selected candidates will be interviewed by a senior member of the Laboratories' staff.

National Institute for Research in Nuclear Science

requires

EXPERIMENTALISTS

for the

Rutherford High Energy Laboratory at Harwell, Berks.

to assist in the:

(1) Development, commissioning and subsequent operation of the 7 GeV Proton Synchrotron (NIMROD).
(2) Study of some fundamental aspects of accelerator and particle beam physics.

Applicants should have G.C.E. at "A" level, H.N.C. in Applied Physics or equivalent. Experience in one or more of the following fields would be an advantage:—

(i) General electronics.
(ii) Production and handling of R.F. power.
(iii) Production and insulation of high voltages, including high vacuum devices.
(iv) Production focusing and measurement of ion or electron beams.
(v) Low temperature technology.
(vi) High vacuum technology.

Salary £570 (at age 20)–£1,005 p.a. or within £1,110–£1,360 p.a. and £1,535–£1,900 p.a. according to age and experience.
Housing and superannuation schemes.

Send Post Card for details to:
Secretary (N.2/110),
Rutherford Laboratory,
Harwell, Didcot, Berks.

UNITED KINGDOM ATOMIC ENERGY AUTHORITY

THE RADIOCHEMICAL CENTRE, AMERSHAM

CHEMISTS AND PHYSICISTS

The use of radioisotopes, labelled compounds and radiation appliances continues to grow rapidly in many branches of medicine, industry and research. Production and development of these important materials affords wide scope and interest for chemists and physicists, and the Centre invites applications from those suitably qualified in organic or inorganic chemistry, or in physics.

Selected candidates will be offered appointments in the Scientific or Experimental Class. A good honours degree is an essential qualification for entry into the Scientific Class, and a pass degree, or an appropriate H.N.C., two " A " level passes in Science subjects, or other equivalent qualification for the Experimental Class.

Commencing salary related to age, experience and qualifications up to £1,365 in the Scientific Class and up to £1,110 in the Experimental Class with prospects of advancement to £2,460 and £1,900 respectively.

Superannuation and housing schemes.

Apply to: **Personnel Officer, The Radiochemical Centre, Amersham, Bucks.**

quoting No. 19/1960/110

COMMONWEALTH OF AUSTRALIA

DEPARTMENT OF SUPPLY

CRYSTAL PHYSICS

Applications are invited for the following vacant position at the Defence Standards Laboratories, Maribyrnong, Victoria:

Position: **SENIOR SCIENTIFIC OFFICER**

Salary: £2,460–£2,655 (Australian currency).

Duties (Pos. No. 53): To take charge of a section engaged in applying X-ray crystallography and electron microscopy to structural problems arising from the chemical, physical and metallurgical work of D.S.L. including interpretation of results; also applying X-ray diffraction to metallurgical examinations and chemical analysis.

Qualifications: Honours degree in Physics and several years' relevant experience.

Travel: Under specified conditions, first class air/sea transport for the appointee and dependants (wife and dependent children) will be provided by the Commonwealth.

Contract Employment: If desired by the successful candidate consideration may be given to entering into an agreement for a three (3) year contract of employment in Australia. In this case the Commonwealth will bear the cost of return fares; together with the cost of removing the successful applicant's furniture and effects up to a maximum cost of £500 (Aust.), £250 each way.

Applications: Forms obtainable from Senior Representative (AV 82/7), Department of Supply, Australia House, Strand, London, W.C.2, with whom completed applications should be lodged by December 7, 1960.

SUNDERLAND EDUCATION AUTHORITY

THE TECHNICAL COLLEGE

Applications are invited for the post of LECTURER in the PHYSICS DEPARTMENT. Candidates must be well qualified and preference will be given to those who have had teaching and industrial experience. Courses leading to the Diploma in Technology and to the General B.Sc. of London University are in operation.

Salary in accordance with the Burnham Scale for Lecturers: £1,370 by increments of £35 to £1,550 per annum.

Further particulars and forms of applications from the **Registrar, Technical College, Sunderland, Co. Durham.**

Applications should reach the undersigned as soon as possible.

Canvassing disqualifies.

W. Thompson,
Director of Education,
Education Offices,
15 John Street, Sunderland

THE INSTITUTE OF PHYSICS

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A Message from the President

I invite those Members who have not yet responded to the personal appeal that the Treasurer and I recently sent to those of them resident in the U.K. to do so at their earliest convenience. I remind them that donations, whether small, medium or large, will be welcome, and serve equally to indicate our members' active support of the scientific and educational work which the Institute and Society is carrying out.

We are indeed, most grateful to those who have already responded (a list of whose names is printed below) and also to the firms who have already contributed, whose names are also listed below.

J. D. Cockcroft

President.

Appeal for the Physics Trust Fund

By November 2 donations or covenanted subscriptions had been received from the following:

(*a*) From members

Dr. D. R. Ashworth
Mr. H. M. Assenheim
Major E. H. W. Banner
Mr. R. Barber
Professor J. D. Bernal
Mr. W. Binks
Mr. H. C. Binstead
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Dr. B. T. M. Willis
Mr. H. J. Wintle
Dr. R. Witty
Dr. E. P. Wohlfarth
Mr. H. Wraight

(*b*) From firms

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Babcock & Wilcox Ltd.
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The Birmingham Post & Mail Ltd.
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Imperial Chemical Industries Ltd.
The Imperial Tobacco Co. (of Great Britain & Northern Ireland) Ltd.
International Combustion (Holdings) Ltd.
International Computers & Tabulators Ltd.
Johnson, Matthey & Co. Ltd.
Kodak Ltd.
Lloyds Bank Ltd.
Low & Bonar Ltd.
The Metal Box Co. Ltd.
Monsanto Chemicals Ltd.
National Provincial Bank Ltd.
Pilkington Brothers Ltd.
Shell International Petroleum Co. Ltd.
The Steel Company of Wales Ltd.
Stewarts and Lloyds Ltd.
Wm. Teacher & Sons, Ltd.
Tube Investments Ltd.
Unilever Ltd.
The United Steel Companies Ltd.
Vauxhall Motors Ltd.
Yorkshire Imperial Metals Ltd.

Of the contributions from members, 97 were covenanted subscriptions for amounts distributed as follows :

Net annual contribution of up to one guinea	62
Net annual contribution of more than one guinea but less than five guineas ...	26
Net annual contribution of five guineas or more	9

The total received or promised by November 2 was :

	£
Gross value of industrial firms' covenants over seven years (including tax recovered)	49,724
Single donations from firms	2,604
Total from industry ...	52,328
Gross value of members' covenants over seven years (including tax recovered)	2,270
Single donations from members	269
Total from members ...	2,539
GRAND TOTAL at 2.11.60 ...	£54,867

Vol. 11, November, 1960

The Postgraduate Training of Physicists

C. G. SUITS

Vice-President and Director of Research, General Electric Company, Schenectady, New York.

[An address given to the International Conference on Physics Education in Paris on August 3, 1960.]

THE point of view of industrial physics needs to be expressed at this conference because this is a large and rapidly growing field of opportunity for the physicist. That this is so is shown very clearly by the statistical information published by J. Henry Barton of the American Institute of Physics, in a recent issue of *Physics Today*.* The data show that in the United States as of 1958, industry was the largest employer of physicists, with 47%, compared with 35% in educational institutions and 13% in government employment. The trends over a five-year period indicate that the industrial employment of physicists is increasing. The figures express the total employment —as of 1958; the current rate at which physicists are going to industry must be substantially higher. Henry Barton's information indicates also, that judging from the employment of physicists, industry has a substantially greater interest in such fields as solid state, electricity and magnetism, optics and acoustics, while the academic physicists have a relatively greater interest in nuclear physics, theoretical physics, atomic and molecular physics and a catch-all category of general physics; whether this is good or bad, I do not know, but I will comment on it below. In any event, the percentage of present employment in these fields is not a sure guide to the percentage of educational instruction in the same fields. I will quote one additional number from the Barton paper: of the physicists employed by industry, a large fraction of them—18%—are engaged in the management of research and development activities.

The increasing employment of physicists by American industry is, of course, evidence of the increasing complexity of the industrial technology of materials and processes, especially in the technical industries where most of these physicists are found. It is also evidence of an increasing level of basic research effort in American industry, where the physicist plays an indispensable role. This is true for example in the General Electric Research Laboratory where physicists pursue science-oriented research in a great variety of fields, frequently on an individual basis, not infrequently associated with researchers in other fields. Somewhat more than 70% of the research staff of this laboratory are of the Ph.D. level, while the company as a whole employs about 1,000 Ph.D.'s principally in the physical sciences.

My Company's point of view of the graduate training of physicists is, of course, that of an industrial employer of physicists. We take the products of our system of graduate education for the pursuit of scientific research. To be more precise, we regard the Ph.D. physicist not as a product of our educational system alone, but a product of his heredity, his environment and his graduate training. Perhaps we have been focusing too sharply on his training, and have been overlooking the importance of his natural endowments as a factor in his performance in scientific research. I will try to interpret our observations in terms of the graduate study and research exposure which these young men have experienced; naturally I shall be on much less firm ground here.

By and large we are well pleased with the Ph.D. physicists who come to us. They are generally bright and ambitious and their scholastic preparation is usually excellent. They generally turn out to be able researchers, although it usually takes a few years to determine their particular research abilities and interests.

In spite of this general feeling of satisfaction with our young physicists we are puzzled by a few things. When a young Ph.D. joins our staff we hope he will be able to do original research—the more creatively, the better. Yet we are puzzled to know how to find out from his graduate record whether he is in fact capable of original research. From his formal course mark we can easily determine that he has been a good student, but that is not enough. He did not receive an academic grade for originality, nor self-reliance, nor energy and drive, nor physical intuition. We obtain the impression that, in some exceptional cases, the young man may have gone through graduate school and have received his Ph.D., without ever having discovered whether he can do research. Even in this situation, however, it generally works out well, for in the course of his apprenticeship he and we learn about his abilities and we can usually accommodate his program to them.

Not infrequently the young physicist comes to us to work in one field, say semiconduction, having taken his thesis research in quite another field, say high-energy nuclear physics. The theory of this case is perfectly straightforward, for the dissertation research was supposed to be a trial run and not necessarily a life work and we rely upon the fact that the student has had a good broad foundation of formal preparation that will, or should, serve him well in almost any branch of physics. Some fields of graduate research tend so to dominate graduate study that by the time the physicist gets his degree he is already highly specialized, rather than generalized. For example, I have the impression that nuclear research, especially high-energy nuclear physics tends to make for intense specialization, and that solid-state research may encourage more generalization—but that is just an impression, and I would expect to find different points of view on this subject. This particular situation relates to the differences in the fields of physics which are emphasized in industry and in educational institutions, as noted in the Barton article.

* *Physics Today*, Jan., 1960.

We have an interest in the matter of specialization because flexibility and a broad range of interests are desirable traits in an industrial physicist. We wish to be able to turn to important new fields, as we or others indicate their importance, and this need can be illustrated by a current example. This year a variety of new fields are open to physicists, under the heading of energy conversion fields which, but a few years ago, would have interested few physicists. These subjects include the thermionic converter, the semiconductor thermojunction, the fuel cell, magnetohydrodynamic power generation, and several more.

The case of the young man with the Ph.D. who has hardly explored his research ability might be worth some further discussion. There are plausible reasons for this situation to arise. An important part of the problem is, I think, the fact that scientific knowledge is expanding so rapidly that formal training is crowding research out of graduate training. By the time the student has satisfied the formal course requirements and, in addition, the optional course offerings which have become almost indispensable, there is very little time left to accomplish a respectable experimental dissertation. The life of the young graduate student is complicated by the fact that in four or five years of graduate work he probably has acquired a wife and family. His relatives and friends are beginning to ask his mother when he is going to get out of school and get his degree. This, of course, everyone now assumes is a foregone conclusion; it is just a matter of time. By now his professors are in a somewhat difficult position too, for the young man has an excellent scholastic record and is very well spoken of by everyone, and to fail to get his degree at this point would be rather harsh treatment. Although there may not have been time for a full thesis research, there usually is some research work which can be assembled and, if the typing is double spaced, it will provide a thesis which will be thick and fairly respectable. Now I am sure that this hypothetical case must be unusual and probably exaggerated, but I am quite sure that one could find such cases. Regardless of the circumstances of individual graduate study, it is a fact that the fund of knowledge with which the modern young physicist must be familiar is increasing at an alarming rate, and although I have not seen statistics to support the view, I think the time required to complete the Ph.D. work is getting longer and longer. Something has to yield, and I suspect it is the quality of graduate research. And I think that is the reason why some of our Ph.D. graduates have not thoroughly explored their research aptitudes by the time they receive their degrees.

This is an interesting but not a serious situation; I present it more as an observation than a complaint. If we, in industrial research, had a choice as between abbreviated formal course work and full research training on the one hand, and full formal course work and a resultant shorter period of research training on the other hand, I think we would choose the latter. The student can, if necessary, serve his research apprenticeship in a large industrial research laboratory. What may happen in the distant, but not too distant future, is interesting to contemplate. Will graduate training in physics then require six or seven years, rather than the present four or five, and former two or three. It is a question of what we will omit from the future course of study for I would view with considerable alarm any further encroachment on the period of productive effort of the research physicist.

The very interesting report which you have received on the Postgraduate Training of Physicists in British Universities*, indicates that much the same problem of scope is being experienced there, although in slightly different form. The report recommends that formal course work should be extended into the postgraduate training period which, in Great Britain, is presently given over almost entirely to research training and apprenticeship. This is certainly sound, and is a necessary consequence of the extent of knowledge. The report notes also that British industrial laboratories would prefer, under present circumstances, to take the physicist at the Bachelor level and provide his research apprenticeship in the industrial laboratory. From conversations I have had with research directors in Great Britain I know that this is true. If formal course work were extended into the graduate period, as recommended in the report, it would probably change this situation substantially.

In the laboratory with which I am associated we very seldom employ a Bachelor in science.† For laboratory assistants we prefer graduates of two-year technical colleges, and for research scientists, Ph.D. graduates. There are exceptions of course, and in some fields we prefer a research engineer. He is generally a Bachelor in engineering who has had a heavy exposure to science and technological courses, frequently into the graduate level. Such specialists are becoming very valuable men in industry, and we need more of them. Because of their emphasis on science and technology, they have had to forego some of the old standbys of the engineering curriculum, such as surveying and machine design; but on the other hand they know something about nuclear resonance and Fermi levels. If they cannot survey, this is of no consequence to us.

I have intentionally not referred to certain classical problems of graduate training in the U.S., because they have been much discussed and much deplored and I have no new suggestions to make. They include the use of the graduate student as a member of a very large research team—where his opportunity for individual development is correspondingly circumscribed. They also include the problem of the graduate student who "inherits" from a graduating student a complete set of experimental equipment and an established procedure for performing one additional research in an extended series of investigations of particular interest to his professor. This student's opportunity for individual development is also circumscribed. Similarly, the employment of graduate students to accomplish relatively menial but necessary technical tasks such as

* *The Postgraduate Training of Physicists in British Universities.* The report of a joint committee appointed by The Institute of Physics and The Physical Society—March, 1960.

† It is perhaps necessary to point out the different standards of the Bachelor's degree in Europe and the United States.—Ed.

those required in the construction of a particle accelerator or in the satisfaction of the requirements of a government or industrial research contract, may not provide an optimum type of activity for the training of graduate students. I hope these practices are uncommon, and that the practical necessities of graduate research can be managed without seriously compromising the student's opportunity for exploring and developing his aptitude for individual creative scientific research.

I must comment on originality and creativity in scientific research. No graduate training which has been devised thus far will ensure the development and flowering of these admirable traits of a researcher. Yet they are of superlative importance to the future progress of civilization. The creative spark in science nucleates a vast resultant and dependent activity that may have immense material and practical consequences; but I do not need to develop this theme in an audience of physicists.

Why do we not do something about creativity during the period of research training ? I think there is little merit in the idea of " developing " originality, but that there are abundant opportunities to recognize creative traits and aptitudes, and to encourage and further them. If creative talents have not been in evidence prior to graduate study, I do not think the student is likely to discover them suddenly during this period. In fact, creative aptitudes must appear very early in life, and at secondary-school level they should perhaps be perceptible. In the belief that this may be so, Union College at Schenectady, N.Y. and the General Electric Research Laboratory are embarking upon an interesting experiment, which has not yet been announced because we are still working out details of the plan. The main outlines of the plan, however, are these. We will bring a group of secondary-school science students to the college for summer study and tutelage. These students will not be selected only for their scholarship, but an effort will be made to appraise exceptional interests and aptitudes in science. The most unusual feature of the plan is the following: each student will undertake a little research project under the individual tutelage of a member of the Research Laboratory staff. We hope that in this way we may discover natural endowments and aptitudes, and encourage them to mature for the benefit of science. Whether we can do anything to recognize and enhance creativity at the graduate level, I do not know. It is so important that it would be worth exploring all possibilities. We now appear to teach problem-solving, and not how to find problems and to appraise them; we teach how to understand, but not how to discover. In effect, we teach the logistics and tactics without teaching the strategics of scientific research. This is a great area of challenge in the teaching of physics at graduate level, and we must make a start at progress toward this important objective.

I would like to return to a statistic from the Barton paper concerning the employment of physicists. Recall that 18% of the physicists employed by U.S. industry are engaged in the management of research and development and that even in educational institutions 4% of physicists are concerned with such work. I consider that this is a very significant statistic, and that it points to an increasing area of opportunity, and obligation, for physicists in particular, and scientists in general. I have not seen the corresponding statistic relating to industrially employed chemists, metallurgists or engineers. But one might accept that a similar situation exists there. Philosophically, it seems to me that with an ever-increasing impact of science on human welfare, on economic well-being, and on the affairs of nations, it is inevitable that scientists should interest themselves in the management of technical work. I refer to it as an obligation. It is more than that—it is a necessity. Either scientists must concern themselves with the management of their kind of work, or their work will be managed by non-technical people who are not in a position to support their decisions with necessary technical understanding. In my experience physicists, chemists, metallurgists and engineers generally make very good managers of research and development. I think that physicists must become increasingly aware of the opportunity and obligation in this area. The day has long since passed when the physicist can retire to his ivory tower in isolation from the world. He must, it seems to me, increasingly and appropriately concern himself with the interpretation, guidance and management of the affairs which have been created as a result of his work. This fact should perhaps be recognized and provided for in the undergraduate and graduate training of physicists. Perhaps we must insist that the already overloaded curriculum include an irreducible minimum exposure to history, economics, and sociology as partial preparation for life in a world of scientific affairs.

I am sure that I have presented more problems than I have solved. They include:

(*a*) the expanding scope of graduate training;
(*b*) the problem of recognizing individual research ability, and providing an opportunity for its development;
(*c*) the preparation for creative research, rather than problem solving;
(*d*) the recognition of the role of the physicist in scientific affairs;
(*e*) the problem of overspecialization in graduate physics.

I recommend these problems for your consideration.

The History of Science in Manchester

J. G. CROWTHER

[A Lecture to the Manchester and District Branch of the Institute of Physics given on February 15th, 1960.]

THE RISE of science in Manchester was due to the industrial revolution. During the second half of the eighteenth century the rapid growth of industry through the mechanization of manufacture and the development of steam power stimulated enquiry into the properties of materials, the principles underlying industrial processes and the provision of power for operating them.

The sudden and vast increase in production, bringing with it swift concentrations of population, created problems of food-supply and sanitation which stimulated revolutions in agriculture and medicine.

In Manchester men's thoughts were urgently impelled to the study of these matters. The Literary and Philosophical Society of Manchester was founded in the house of Dr. Thomas Percival on February 28, 1781. As John F. Fulton has remarked, "Thomas Percival wrote the greatest book on medical ethics that has ever appeared in English, and in addition made scientific contributions of the first importance to public health and the problem of putrefaction."

Percival himself had been the first student enrolled at the Warrington Academy when it was opened in 1757. This institution was founded to provide higher education suited to the requirements of the bankers, merchants and industrialists who wished to secure a suitable edutation for their sons, which could not be obtained in Oxford or Cambridge owing to their curricula, and exclusion on the ground of non-conformity.

Warrington Academy was not conceived as a local institution. Students came from all quarters, including the British Isles, the West Indies and America. We are told that not since the Middle Ages had there been such a mingling of students in a British institution of higher education.

Besides its notable first student, it had a particularly remarkable professor in the person of Joseph Priestley, who held the chair of languages and *belles lettres*. While he was at Warrington he began to learn chemistry from the professor of natural philosophy.

The ideas of the Warrington Academy were incorporated in the laws of the Literary and Philosophical Society. In its early years the Society went through stirring times. When the house of Joseph Priestley was burned down in Birmingham by the mob in 1791 because of his sympathies with the French Revolution, a resolution "that this Society do write to Dr. Priestley, expressing their concern at the losses he has sustained by the late disgraceful riot . . ." was proposed in the Society, but rejected. Whereupon, Thomas Cooper, James Watt junior, Joseph Priestley junior, and other members resigned from the Society. In the following year, 1792, Thomas Cooper and James Watt junior were sent by their Manchester friends as delegates to deliver fraternal greetings to the Société des Amis de la Constitution in Paris. Edmund Burke got to hear about it, and denounced them in the House of Commons. "On this detested occasion," he said, "Mr. Cooper and Mr. Watt carried the British colours. They were locked in the fraternizing embrace. They received the fraternizing kiss. They went from the hall of the assembly to the hall of the Jacobins, where they kissed the bloody cheek of Marat. . . ."

There is a rumour that Marat had actually been on the staff of Warrington Academy, disguised as a teacher of foreign languages, and had nearly become the husband of the celebrated poetess and hymn-writer who subsequently married Mr. Barbauld. No wonder one of Mrs. Barbauld's most famous lines is :

"Life ! I know not what thou art . . ."

While Marat certainly spent some time in England, and was a chemist, the rumour that he had been at Warrington appears to be ill-founded.

Immediately after these events John Dalton arrived in Manchester. Dalton was the son of a weaver. He had gone into domestic service at the age of eleven in the household of a well-to-do Quaker with scientific interests. This gentleman noticed his studious tendencies, and gave him personal tuition. By the age of twenty-one, Dalton was able through private study to lecture on mechanics, optics, pneumatics and astronomy. He learned a little of ancient and modern languages, and mastered the calculus. He started systematic meteorological records, which he kept up for fifty-seven years, making during that time 200,000 observations.

Dalton was engaged in Manchester as a tutor in 1793, and joined the Literary and Philosophical Society in 1794. He came to the city during a lively period. The young Society had included Lavoisier, Priestley and Volta among its earliest honorary members. Manchester became the chief centre in England for the development of Lavoisier's new chemistry.

Dalton himself was really more of a physicist than a chemist. He had pored over Newton's *Principia*, and, as he himself says, had learned from it the atomic theory. Newton had shown that Boyle's law could be mathematically deduced on the assumption that gases consist of atoms, and had thereby converted the atomic hypothesis from a philosophical speculation into a scientific theory. It was this which emboldened Dalton to set about trying to explain the properties of gases, and the exact chemical data established by Lavoisier, in terms of atomic theory.

In addition to his application of the atomic theory in chemistry, he made pregnant observations and discoveries in other directions. By simultaneous observations at Kendal and Keswick in 1793, he proved that the aurorae were occurring at a height of 150 miles. He noted that they were connected with terrestrial magnetism. He thought that the aurorae indicated the existence of an elastic fluid of a ferruginous nature above

the atmosphere. Dalton was groping towards the discovery of the ionosphere.

His studies of the atmosphere led him to make experiments on the production of heat and cold by the compression and expansion of air. He expressed the opinion that all gases should be capable of liquefaction, and said " we ought not to despair of effecting it in low temperatures, and by strong pressure." Almost simultaneously with Gay-Lussac he discovered that heat produces the same degree of expansion in all gases. He prepared the ground for Joule, by focusing attention on the quantitative aspects of the effects of heat and pressure on gases.

Joule, unlike the notion of him and his work, which has been conveyed from generation to generation of students, was one of the most brilliant and intellectually exciting scientists. The misleading notion of him as merely a very painstaking and rather dull experimenter has arisen from the almost exclusive reading of his later papers on the measurement of the mechanical equivalent of heat, and not studying his early papers in which he discovered it. These show that Joule sprang at the age of eighteen into the front rank of experimenters.

His grandfather founded a brewery in Salford, and made a fortune. The ownership of the brewery passed to the father of the scientist. Joule and his elder brother were educated at home by private tutors. At the age of fifteen Joule began to do some work in the brewery in order to learn the business. There are many processes of scientific interest in breweries, which have provided the starting-points of numerous scientific developments.

Joule was born in 1818, and at the age of twelve amused himself, together with his elder brother, in watching the first trains between Liverpool and Manchester passing to and fro. He saw the triumph of the steam engine in its most striking form at an impressionable age. He was already interested in scientific toys, and he and his brother entertained themselves by giving electric shocks to the family servants. Before the age of sixteen Joule had made his first static electrical machine, and Leyden jars.

In 1834, Joule's father decided to send his boys to Dalton to receive instruction in chemistry, probably to qualify them for future management in the brewery. Dalton was sixty-eight years old, and still earning pocket money by teaching children. The boys visited him for two weekly lessons of one hour each. During the next two years, Dalton insisted on going over again the arithmetic and geometry they had already learned. After this, he suggested they should now go on to the higher mathematics. The boys, who were very keen to start on experiments, declined.

Dalton did not believe in any nonsense about experiments as an introduction to chemistry. He was the first of what are nowadays called theoretical chemists. Joule learned from him something far more important than conventional laboratory routine : independent and critical thinking.

Joule had extraordinary gifts for devising, constructing and manipulating apparatus. His most important need was appropriate philosophical direction, and he probably learned this from Dalton's conversation and published papers. One of the striking features of Joule's early papers, written before he was twenty, is their independence of tone. This is rare in papers of young research students, who would naturally feel that any remarks which might be regarded as over-confident would be unseemly. In this respect, Joule enjoyed one of the advantages of not passing through the educational system. He never went to school or university.

Joule's original accounts of all of his experiments between the years 1839-1871 still exist. They are contained in six laboratory notebooks, one of which was an old exercise book from his boyhood. His fundamental work started from his investigations of electrical machines. Since the discovery of electromagnetism in 1820 by Oersted, Sturgeon had invented the electromagnet and the commutator, and Faraday had discovered electromagnetic induction. With these, the first crude dynamos and electric motors were made. Joule set out with the aim of improving the efficiency of the electric motor, which seemed to offer a possibility of superseding the steam engine as a source of power. The idea of the conservation of energy had not yet been clearly conceived, and Joule, like others, seems to have had a notion that the electromagnet might somehow make energy. In his first paper he described, with exact measurements, various arrangements of electromagnets and coils in an experimental motor with adjustable parts, with the aim of discovering the most efficient design.

He measured the efficiency by finding the rate at which the motor could raise a given weight, expressing his results in foot-pounds. He published this in his second paper, when he was nineteen years old. As Osborne Reynolds remarks, it was the first recorded absolute measurement of work in connection with the philosophical study of physics.

In his fourth paper, published when he was twenty-one, he stated the law of attraction between two electromagnets, that is, if M is the attraction, E the current, and W the length of wire in the coils, then $M = E^2W^2$.

In the process of analyzing the efficiency of the electric motor, Joule investigated the relation between the amount of heat produced in the motor in relation to the amount of current going through it. He discovered that the heat produced in a conductor is proportional to the product of the resistance and the square of the current.

He submitted an account of this discovery in his first paper to the Royal Society, which refused to publish it except in brief extract. Schuster subsequently asked Joule how he felt when he heard that the Society had refused to publish his paper in full. He answered : " I was not surprised. I could imagine those gentlemen in London sitting round a table and saying to each other : ' What good can come out of a town where they dine in the middle of the day ? ' "

Joule went on to measure the amount of heat produced, that is, the amount of energy lost in the form of heat, in his electric motor, by, in effect, suspending the running motor in water, and measuring the rise in temperature in a given time.

He discovered and measured the mechanical equivalent of heat by an intricate analysis of the results of this experiment. The mode of his discovery was infinitely more ingenious and instructive than the experiment with

the paddles which got into all the textbooks. He discovered the mechanical equivalent of heat through the marriage of the work of Watt and Dalton with that of Faraday and Sturgeon.

The science of Dalton and Joule was limited on the collective side. Neither of them contributed much to organized research. After Dalton, Joule and other brilliant individuals, the collective organization of research and teaching in Manchester became a crying need. The foundation of Owens College was a contribution towards meeting it. The college was opened in 1851, and was accommodated in Cobden's old house. By the 1870's it had become a brilliant institution. Its professoriate included Balfour Stewart in physics, Osborne Reynolds in engineering, W. C. Williamson in natural history, Stanley Jevons in political economy, Adolphus Ward in history, Bryce in law, and Roscoe in chemistry. The first chair of organic chemistry in England was added in 1874, and Schorlemmer, who became a friend of Friedrich Engels, was brought to England to fill it.

A very interesting account of what Owens College was like in those early days was left by J. J. Thomson. He described how the gifted professors and the crowd of students stumbled over each other in the cramped old house, and how they could not avoid getting to know each other in these conditions. In spite of wretched or non-existent laboratories, splendid work was done. Thomson entered Owens in 1871 as a student of engineering, when he was a boy of fourteen. The college moved to its new and more spacious quarters during J.J.'s last two years, but he says that his most vivid recollections of his Owens days were always of the crowded life and inspired atmosphere in the old Cobden house in Quay Street.

Balfour Stewart was a physicist of original views. He announced the law of radiation, which was rediscovered by Kirchhoff. His work on terrestrial magnetism led him in 1882 to suggest the existence of electrically-conducting layers in the upper atmosphere. He pointed out the dynamo action of these conductors, as they cut across the earth's lines of magnetic force through convective movements of air, and anticipated the nowadays fashionable subject of cosmical electrodynamics.

He had a profound insight into the principles of equivalence and reciprocity in nature. He suspected that when chemical changes take place, they are accompanied by changes, and not re-arrangements, of mass. He set young J. J. Thomson on weighing reacting mixtures of iodine and mercury to try to detect the change of mass. On one occasion, the mercury did not react with the iodine, and J. J. picked up the flask to see what was the matter. It exploded in his face, and he nearly lost his eye-sight. Many bits of glass had to be taken out of one of his eyes.

Balfour Stewart was not a good routine lecturer or disciplinarian. He regarded himself as a student, with the same status as other learners. Administrators sometimes took a poor view of his activities. On receiving one day a somewhat tart communication from the Principal, who had the habit of writing letters which started very nicely and then ended with unpleasant comments, Balfour Stewart remarked that "every billet has its bullet."

Even more remarkable was the professor of engineering, Osborne Reynolds, J.J.'s first professor. Reynolds was only twenty-six when he was appointed to the chair of engineering at Owens. In addition to his youth, he had the most uncompromising intellectual outlook, combined with a chequered command of the spoken word. His scepticism of conventional ideas reached sublime heights. He maintained the general thesis that when a scientist of established reputation has the whole scientific world against him, he must be right; a tradition which seems to have been very fruitful in Manchester. He hated easy agreement, and he carefully brought up his son to do the opposite of everything he told him to do. He thought it would develop his independence and originality. Schuster has described how, when he called on him one day, he was playing with his little boy. "Come here," he said, and the boy immediately went away. Reynolds was delighted.

It is notable that many of Manchester's most brilliant students graduated in or read engineering. This is due in part to the philosophical influence of Reynolds. They included J. J. Thomson, Sydney Chapman and J. D. Cockcroft.

Reynolds was born with a passion for mechanics. His father was a headmaster and clergyman who had taken a high degree in mathematics at Cambridge, and also had a taste for mechanics. Reynolds was educated at home, and at the age of nineteen went into an engineering workshop "to learn in the shortest time possible how work should be done, and as far as time would permit, to be made a working mechanic before going to Cambridge to work for Honours."

He always attacked difficult fundamental problems, with results that are of ever-increasing importance. His researches on turbines, condensers and heat-transfer are on the main line of engineering development to-day. He largely created the science of experimental hydrodynamics, by establishing the principles on which the behaviour of full-scale engineering constructions could be deduced from that of models. It has been pointed out that the principles of C. A. Parson's development of the steam turbine were implicit in Reynolds's work. He discovered the relation between the critical velocity at which a fluid-flow changes from stream-line to turbulence, and introduced experimental techniques for investigating the flow of actual fluids. The development of the use of models for the design of aircraft and dams arose out of his work.

J. J. Thomson has described how he used to forget that he had to give lectures, and when his class assembled, a laboratory assistant often had to go off and try to find him. When he had been reminded, he would rush into the lecture theatre, pulling his gown on, and open one of Rankine's textbooks at random. A formula would catch his eye, and he would instantly announce to the class: "That's wrong." He would go up to the blackboard, and work it all out from first principles, muttering to himself. After repeated false starts, the board would be covered with incorrect calculations, but as the dust of chalk gradually settled, the class would detect in a corner

a derivation which did, in fact, coincide with the formula in Rankine's book.

Schuster began his association with Manchester in 1870. He came there from Frankfurt at the age of nineteen, owing to what he called an "uncomfortable atmosphere," which was growing in Germany. He entered the family textile business, and went to evening classes at Owens, and then became a day-student. After spending a year under Balfour Stewart, he studied at Heidelberg under Kirchhoff. Then he worked under Clerk Maxwell and Rayleigh in the recently-founded Cavendish Laboratory, and he gave lectures at Owens on Clerk Maxwell's new theory of electromagnetism, which J.J. attended as a student.

Schuster was appointed professor of applied mathematics at Owens in 1881, and succeeded Balfour Stewart as professor of physics in 1888. He advanced the mathematical formulation of Balfour Stewart's "dynamo" theory of terrestrial magnetism, and suggested that the conductivity of the upper atmosphere was due to ultra-violet rays from the sun. His interest in cosmical physics was strengthened by his work on eclipse expeditions. He was the first to photograph the spectrum of the solar corona.

Schuster's studies of spectra from discharge tubes led him to the investigation of electric discharges in gases at low pressure. He independently suggested that these were due to ions. He made the first determinations of the ratio between the charge and mass of an electron by means of the magnetic deflection of cathode rays, but he missed forestalling J. J. Thomson in the discovery of the electron. Schuster's mind was not quite sufficiently incisive to clinch the point.

Schuster's many and important discoveries are not, however, his chief claim to fame. This is in the organization of Manchester physics. When he first taught physics at Owens, only ten students took the subject ; when he retired in 1907, there were 250. He created and organized a fine new laboratory.

The supreme achievement of Schuster's life was to bring his department to the most advanced state of efficiency, and then seek to place it at the disposal of the best physicist in the world by himself retiring. Through careful and persistent management, he succeeded in ensuring that Rutherford, then thirty-six and at Montreal, should succeed him. When everything had been safely arranged, Schuster resigned his chair at the age of fifty-six. It was very much a voluntary retirement for he lived to the age of eighty-three.

The department that Schuster bequeathed to Rutherford was furnished down to the last detail, even including Hans Geiger as personal research assistant, and a "young, energetic and exceptionally capable" lab-boy named William Kay.

Schuster arranged that Rutherford should receive a relatively very large salary. It was £1,600 a year, and equal to the combined salaries of nine other graduate members of his staff. In addition to all this, Schuster had created and endowed a special readership in theoretical physics. It provided the combination of forces that was needed, and had very important consequences.

Rutherford's Manchester period was the greatest of the three periods into which his research life naturally fell. Soon after he arrived at Manchester, where he found that besides having a splendidly equipped laboratory, he had many more research students than before to pursue his ideas, he drew up a plan of thirty research topics, and started the experiments which led to the establishment of the nuclear theory of the atom, and the foundation of nuclear physics.

With Geiger he developed the electrical counter. He made exact counts of the number of α-particles emitted by a given quantity of radium in a second, and estimated the electrostatic charge on an α-particle. It came out at $4{\cdot}65 \times 10^{-10}$ units, and agreed closely with the figure which Planck had deduced eight years before from his quantum theory. Rutherford had hitherto been prejudiced against the quantum theory, but when his own experimental results agreed with it, he began to revise his opinion. He went round telling his friends : "There is more in old Planck than meets the eye."

One of Rutherford's most remarkable gifts was his ability to throw his most strongly-held opinions overboard when they were in conflict with experimental fact. His conscious thoughts were not a very good expression of his profound intuitions. He hated mere intellectual subtlety and felt uncomfortable in its presence. He did his real thinking in his unconscious, and his blustering was a way of protecting the embryonic development of new ideas that were being formulated in his imagination. As Bohr once observed : "Rutherford is not a clever man ; he is a great man."

Great though the events were in the Cavendish in 1932, those that had occurred at Manchester before were greater. Geiger and the eighteen-year-old research student Marsden discovered that there was an abnormally large number of big deflections when α-particles were fired at pieces of gold foil. Rutherford saw that this implied that the atom must have a nuclear structure

It is now often said that Rutherford did not believe that atomic energy would ever be released. I must say that this is not quite my impression, either from his works, or from the man himself. In his early Canadian period he wrote about his determination of the amount of energy locked up in atoms in a manner which indicated that he considered it highly significant for science ; and for Rutherford science always included experimental science. As he grew older, he became more and more careful in his expressions of opinion on the release of atomic energy, and after the discovery of the neutron and the disintegration of atoms by artificially accelerated particles he became very careful indeed. I believe that what he was doing was not expressing his disbelief that atomic energy would ever be released, but taking what might be called intellectual security precautions, to see that the event came to occur under proper circumstances.

He hated sensationalism and vulgar exploitation. Shortly after the discovery of the neutron, a physicist from Europe called on him, and proposed that they should jointly take out a few fundamental patents. Rutherford became extremely angry, and his visitor fled, unable to understand what he was so annoyed about.

I believe Rutherford understood very well what the discoveries in his laboratory portended, but he was determined that not a word should be said promising the release of atomic energy, until the decisive experiment had been performed.

Rutherford's attitude of being entirely negative until there was good reason to be positive was illustrated by his attitude towards the theory of the nuclear atom. It was evident to him that it could not be explained by Newtonian mechanics, but this did not cause him to announce at once that Newtonian mechanics must be superseded.

The solution of the theoretical problem was found by the young Danish physicist Niels Bohr. He saw that the nuclear atom could be given stability on the principles of the quantum theory. Bohr went first to Cambridge, but did not find the atmosphere encouraging, so he decided to go on to Manchester. Rutherford was careful to view both Bohr and his ideas with caution. He said that he found " the mixture of Planck's ideas with the old mechanics makes it very difficult to form a physical idea of what is the basis of it all." But as Bohr elucidated the hydrogen spectrum, Rutherford observed that the theory was " very ingenious and seemed to work out well."

A particular feature of these events is that it was Schuster's readership in theoretical physics which subsequently enabled Manchester to retain Bohr, and ensure the collaboration between Rutherford and Bohr. They were the perfect complements of each other, and ensured that the new nuclear physics should develop in a balanced manner, which has enabled it to become so fertile.

In glancing at some of the chief events in the history of science in Manchester, several things stand out. The first is that there has been a close relation between the brilliance of scientific developments in Manchester and the general pulse of life in the community at large.

In the first days, the Manchester scientists took over the lead from their Birmingham friends in developing the science created by the Industrial Revolution. They were in touch with the French Revolution and the scientific developments stimulated by it, and they took the lead in combining the British atomism of Boyle and Newton with the French logic of Lavoisier.

The next significant thing is the fact that the collective development and teaching of science began, in the main, with the establishment of Owens College in the house of Cobden. This necessary development was characteristically connected with the leading exponent of the Manchester social philosophy of the nineteenth century, the free-trade school which expressed the driving social force of the period.

Schuster represented Manchester science in its full wisdom and maturity. During his time, Manchester achieved the summit of its power and wealth, and Schuster placed Rutherford on Manchester science like a kind of crown.

Manchester science has always been at its greatest when in close relation with the creative social forces of the period, and nourished from roots deep in the needs and life of the community.

To-day, its main problem is to ensure that its aims and form of organization conform with the creative social forces of our time. These are not of the same character as those of the Industrial Revolution, or of the free-trade days of Cobden, but of a new kind of planned social order, in which science has an essential, and perhaps a commanding part. It is plain that to-day the problems of organizing and using science are becoming as important as making scientific discoveries ; for if the multitude of discoveries is to lead to social chaos and destruction, what is their use ?

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Physics and Technology: Scotland in Decline

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[An opening address to a conference on the teaching of physics, held in Glasgow on October 14, 1960.]

"WHAT's wrong with Scotland? is a question that has been asked (and answered) with alarming frequency during the last few years. The question is a good one, for unemployment returns and other industrial statistics show clearly enough that our country does not enjoy in full measure the prosperity now so evident south of the border. The answers are nearly always wrong because one serious and perhaps decisive factor in the situation—the neglect of technical education—is seldom acknowledged or examined.

Let us consider first why technical education is important in Scotland, secondly how it is being neglected to-day and thirdly what should be done to improve matters.

The importance of technical education derives from the fact that Britain's economy depends to an ever growing extent on the mastery and industrial application of scientific ideas. This movement, one of the most striking in the history of civilization, began in Glasgow just 200 years ago. The industrial revolution was brought about by the efforts of four men, all members of the university staff, working in the Old College in the High Street during the period 1757-1764.

First among them was Joseph Black. He was responsible successively or simultaneously for the teaching of anatomy, botany, chemistry and medicine but is known to us as the physicist who discovered latent heat and specific heat. James Watt, mathematical instrument maker to the university, owed much to Black's instruction and encouragement in the work which led to the invention of the separate condenser and the double acting steam engine. While these two men were laying the foundation of the age of steam Adam Smith, the professor of moral philosophy, was pondering the economic structure of an industrial community; he was indeed the first economist in the modern sense. John Anderson, the cantankerous professor of natural philosophy, was the first to see the need for technical education. His courses in applied science drew enthusiastic crowds of mechanics and artisans. When he died in 1796 his will contained an ambitious scheme for a technical university. His estate was insolvent but the ideas were welcomed and funds were soon raised to establish Anderson's Institution, afterwards Anderson's University and now the Royal College of Science and Technology. One of the early professors in the new college was George Birkbeck. The London Mechanics' Institute which he helped to found, along the same lines as Anderson's Institution, in 1824 is now Birkbeck College. It marked the beginning of technical education in England.

For more than 100 years, until about the beginning of the present century, Scotland led the world in the application of scientific ideas to industrial problems. The ideas did not always originate in Scotland. Then, as now, there was a distinction between the basic research, which might be done anywhere, and the practical applications, which depended on occasional flashes of inspiration at the proper place and time.

To mention one example, the linen bleaching industry (immensely important in the Glasgow area) was revolutionized when in 1787 Watt suggested large scale exploitation of the bleaching action of chlorine, discovered only two years earlier by Berthollet. A process which originally needed six months in a bleaching field could now be completed indoors in a few hours. The manufacture of bleaching powder, invented by Charles Tennant in Glasgow, soon formed a substantial industry on its own. Early in the 19th century the Tennant factory at St. Rollox was among the largest chemical works in Europe.

When Glasgow's prosperity faltered with the collapse of the tobacco trade after the American War of Independence, new industries were quickly established. Textiles, chemicals, shipbuilding, coal, ironfounding, motor vehicles and aircraft all contributed in turn to the city's prosperity. To-day many of these industries have dwindled sadly. Clyde-built ships formed 14 per cent of the world's output in 1949 but under 4½ per cent in 1959. A century ago Scotland provided more than 90 per cent of all the world's imports of pig iron. Production began to fall some 50 years ago and efforts to reinvigorate the industry are now hampered by high fuel costs. The steel industry, closely allied with shipbuilding, has had a declining share of British output for many years.

On the other hand, the newer industries have not had much success in Scotland. Electronics, automation, aviation, plastics and scientific instrument making have not yet secured a firm footing. The opening or extension of a factory in any of these industries—a commonplace event in England—attracts newspaper headlines in Scotland.

Such development as there is in the science-based industries of the 20th century is not in general brought about by native ingenuity or capital. According to Mr. R. H. S. Robertson (writing in the *Eugenics Review*, July, 1960) less than 1 per cent of the major post-war industrial projects in Scotland have been pioneered by Scots. The rest have originated in England, the United States, Canada, Holland or Italy.

In the 1860's Alfred Nobel, the Swedish chemist, set out to make nitro-glycerine into a safe explosive.

The first result of his researches was the invention of dynamite. No one in England would finance his process. He therefore came to Scotland, raised funds in the Glasgow area and started the Ardeer works, now one of the greatest explosive factories in the world. There are plenty of Nobels to-day but they find little encouragement in Scotland. Nearly all of Britain's science-based industry is in the south of England where many small concerns have, since the 1930's, built themselves into big enterprises by the vigorous exploitation of scientific ideas. These activities are still progressing briskly; why are they hardly ever seen in Scotland ?

To answer this question we may start by considering the partnership of education and technology. It is evident that science-based industry cannot thrive without good facilities for technical education. The old-style apprentice, who still survives in a few industries, was a boy who made the tea and learned his craft by working on the shop floor for several years. The new-style apprentice starts with a five or six year secondary school course. He continues his education (at his employer's expense) by attending day release classes leading to national certificates and, if he has the aptitude, to higher qualifications. He provides the skill and knowledge to bridge the gap between the basic ideas of the research laboratory and the industrial or commercial reality. National Certificates are awarded in several branches of engineering and science; the courses in applied physics are being followed by a rapidly growing number of students. This is not surprising, since the methods and ideas of physics are fundamental in so many of the newer industries.

Scotland's contribution to technical education at the National Certificate level can be assessed in a number of ways. First we may look at the extent to which day release is used in different industries for the training of young people. Table 1 gives a gloomy picture. The figures are all the more depressing when it is remembered that day release is reckoned in some industries as one of the employed person's benefits when negotiating wage scales. Many of our young people are paying for the privilege of further education but are not having the benefit of it.

TABLE 1.

Day release from industry.

Boys and girls under 18 years of age released by their employers for part-time technical education during working hours.

Industry	*% of employees under 18 enjoying day release*	
	England and Wales	*Scotland*
Gas, electricity, water ...	82	40
Mining	60	50
Metal manufacture	49	16
Construction	44	22
Engineering and electrical goods ...	41	47
Vehicles	39	19
Shipbuilding	38	19
Chemicals	37	9
Professional and scientific services ...	31	7
Transport, communication	25	4
Paper, printing, publishing	19	5
Timber, furniture	8	4
Textiles	6	3
All industries	20	11

Next we may consider the number of National Certificates awarded in Britain. On a population basis the proportion ought to be about 1 to 8½ between Scotland and England (including Wales). In fact, as Table 2 shows, the figure is about 1 to 12. In applied physics the situation is even less satisfactory. From Table 3 it will be noticed that for every Ordinary National Certificate awarded in Scotland there are 30 in England. At the Higher National Certificate level the ratio is about 1 to 17.

TABLE 2.

National certificates awarded 1957-8-9.

	Ordinary		*Higher*	
	Scotland	*England and Wales*	*Scotland*	*England and Wales*
1957	1,409	16,176	776	8,796
1958	1,495	18,028	874	9,647
1959	1,523	19,654	825	10,546

TABLE 3.

National Certificates in Applied Physics, 1957-8-9.

	Ordinary		*Higher*	
	Scotland	*England and Wales*	*Scotland*	*England and Wales*
1957	12	254	11	112
1958	7	405	6	169
1959	19	515	11	203

It might be supposed that fewer boys and girls in the 15-17 age group are attending technical college classes because more of them stay on at school. The figures here are surprising (Table 4). The proportion of young people aged 15, 16 or 17 receiving full-time education at school is distinctly smaller in Scotland than in England. From the figures in this table it may be calculated that some 10,000 Scottish children discontinue their education every year though they are presumably of the same intelligence as their English contemporaries and therefore capable of benefiting from further instruction.

TABLE 4.

Boys and girls (aged 15, 16 or 17 at last birthday) attending school or day release courses, 1959.

	England and Wales	*Scotland*
Number in group ...	1,771,000	230,900
% still at school ...	24	18
% attending day release classes ...	14	7·5

These are the lost thousands. Many of them have little chance of success in the age of science. In due time they will swell the ranks of the unemployed or, if they are more fortunate, the reserves of unskilled and semi-skilled labour so useful to employers from other countries who wish to assemble their products in Scotland.

One reason for the dearth of candidates in the National Certificate examinations is the dearth of colleges where they can study. In Glasgow, for example, there are no courses at all for the Ordinary or Higher National Certificates in applied physics. It is astonishing that this great city cannot, in one of the most significant fields of modern technical education, offer the facilities enjoyed by such small English towns as Letchworth, Kingston-on-Thames and Worcester. The deficiency cannot be excused by telling the prospective students to take a bus to Paisley or a train to Edinburgh, where

excellent courses are available. It is sad to find Glasgow, the birthplace of technical education, without the means of continuing the traditions that made the city so famous in bygone days.

It may be objected that if there is so little science-based industry in Scotland there is no need for technical colleges. Let us wait, we are sometimes told, until employers start asking for people trained in applied physics before building colleges to teach them. To advance this argument is to ignore the facts of history, The scientist, the technologist and the technician are, in the main, products of the educational system, not of the industrial system in which they hope to work. A coherent demand for technical education facilities will not arise from an assortment of industries, but the existence of technically trained people will facilitate the growth of new industries. If the question is asked: which comes first, the technical colleges or the science-based industries? the answer must always be: the technical colleges.* To demonstrate the validity of this judgement we may recall the story of the aniline dyes. The basic chemical discovery was made in 1856 by W. H. Perkin (encouraged by Pullars of Perth, the dyers). He showed that new pigments, much superior to those provided by nature, could be prepared by using the methods of organic chemistry. The essential raw material—coal—was cheap and abundant in England where a large market awaited the final products. Yet the new industry developed in Germany, using Perkin's ideas and imported coal. The German success depended on a superior educational system, established by Liebig and von Humboldt in the early years of the 19th century to provide teaching of a high standard in science and other subjects at every level from the primary school to the university. Perkin's discovery was exploited in Germany, because that country had the means of producing the scientists that the situation demanded. The later success of German electrical engineering can be traced to the same cause.

In those days the great need was for professional scientists. To-day we have an adequate supply of graduates in science and engineering; the need is for large numbers of technicians who understand the scientific foundations of the craft. We are not training enough of them in Scotland. Until we do, it is idle to hope for prosperous industries based on 20th century science.

The picture that we now see is not a cheering one, for it shows how Scotland has forgotten the lessons so brilliantly demonstrated 200 years ago by Black, Watt and Anderson. What can be done to improve the outlook ? One popular remedy is to introduce science and industry from outside, by planting factories and government research laboratories in Scotland. This has already been done on several occasions, though the promised benefits have not appeared. Scotland's three large atomic energy establishments at Chapelcross, Dounreay and Hunterston will cost nearly £100,000,000 in total. They contain scientific instruments worth several million pounds, of which all save a tiny fraction have been made in England. No large native enterprise has arisen to supply the specialized needs of these establishments, though several English firms have found useful and profitable tasks, even in the far north. The Scientific Instrument Manufacturers' Association has 170 members; Scotland, with a rich market waiting to be exploited, provides only 7 (and 3 of those are branches of English firms).

One of the world's greatest engineering research laboratories has been built at East Kilbride, but Scottish firms make a very modest use of its extensive facilities. Here and at Dounreay the proportion of Scots among the senior staff is no greater than at Harwell, Farnborough or any of the large English laboratories.

To build such laboratories before the country is ready for them is to put the cart before the horse. Benevolence of this kind will do no good in the long run, however attractive it looks in the short view. What must be done as well is to create the atmosphere in which science and technology will flourish anew by the expression of that native ingenuity which served Scotland so well during the 18th and 19th centuries. To begin with we should, of course, expand the facilities for technical education at the National Certificate level, so as to fill some of the gaps now obvious.

For the future there must be action of a more fundamental kind. Many of the difficulties that have been mentioned here are the natural consequences of living in a country where science is not taken seriously enough. How else can we describe a country which, fighting for economic survival in a world dominated by technology, allows the basic sciences of physics and chemistry only the status of half subjects in the school curriculum and the leaving certificate examinations. There was a time when Scotland pioneered the industrial development of ideas from the laboratory. Many of the country's traditional industries were, in their own day, just as exciting as atomic energy or automation appear to us. To-day some are dying and some stagnating. These changes occur in other countries too—but what we lack is the flood of new ventures to take the place of the older industries. Little can be done immediately but we should be planning for the 1970's and 1980's. The Minister for Science should have an office in Scotland, for there is no part of the realm more clearly in need of his help and guidance. There should be a Scottish Parliamentary and Scientific Committee, so that scientific problems affecting the life of the nation can be continually reviewed at a high level.

These are some of the ways in which Scotland, by a long and hard effort, may regain the place that she once enjoyed in the world's industry and technology.

* A detailed analysis of this matter is given by D. S. L. Caldwell in *The Organisation of Science in England* (Heinemann, 1957.)

Salary Survey—1960

THE REPORT OF A SURVEY OF SALARIES AND EMOLUMENTS RECEIVED BY FELLOWS, ASSOCIATES AND GRADUATES OF THE INSTITUTE OF PHYSICS AS AT MARCH 1, 1960

(This report is not to be reproduced in whole or in part without the written permission of The Institute of Physics and The Physical Society.)

FIVE surveys of salaries and other emoluments received by members have now been conducted by The Institute of Physics since 1948; the present report relates to salaries effective on March 1, 1960. Earlier surveys were conducted in 1948, 1951, 1953 and (October) 1956. The reports of these surveys have been widely requested, and apparently valued, by industrial employers, Government departments, public authorities and others concerned with salaries of scientists, and it is therefore extremely important that the significance of the data here presented should be clearly understood.

This report is not a guide to the salaries appropriate to all graduates in physics; much less is it a scale or set of scales recommended by the Council of The Institute of Physics and The Physical Society. The report is a factual summary of the emoluments received by members of certain grades of The Institute of Physics and, since there is a clear and substantial difference between the average incomes of members of the same age in the different grades, due regard must be paid to the qualifications implied by these gradings.

The survey was conducted before the amalgamation of The Institute of Physics and The Physical Society; enquiry cards were sent to the members of the grades which now constitute the professional membership of the amalgamated body who were resident in Great Britain. These are Fellow of The Institute of Physics (F.Inst.P.), Associate of The Institute of Physics (A.Inst.P.) and Graduate of The Institute of Physics (Grad.Inst.P.). The significance of the grades is as follows. For Graduateship an approved degree or other qualification in physics (in general, an honours degree) is the essential requirement but candidates are also required to be engaged in suitable work in physics. For Associateship, in addition to a degree a period of approved experience—three or five years according to the degree held—is essential and this is carefully investigated, some evidence of originality, initiative and responsibility being demanded. For Fellowship of the Institute the period of experience is not less than seven or ten years (according to its nature) and the standard demanded is very high; only a minority of professional physicists would be expected to be able to qualify eventually for this grade. The minimum ages for the grades are 21 years for Graduateship, 25 for Associateship and 30 for Fellowship; it is unusual for candidates to have had the necessary experience for the two senior grades before the ages of about 28 and 34 respectively.

DATA RECEIVED

In the present survey there was a higher percentage return from members than in any previous survey. The response (with 1956 percentages in brackets) is shown in Table 1.

Table 1.—*Cards sent and returned.*

Grade	*Cards sent*	*Returned*	*% return*	*1956 return*
Fellow (F.Inst.P.) ...	858	635	74%	(67%)
Associate (A.Inst.P.) ...	2,187	1,724	79%	(76%)
Graduate (Grad.Inst.P.) ...	1,352	1,067	79%	(73%)
...	4,397	3,426	78%	(73%)

As far as possible the survey was conducted in the same way as the previous one so as to make comparison easy; for the same reason the present report follows closely the pattern of that of 1956. A further advantage of keeping the same basis of survey and report is that the 1956 survey was planned in conjunction with officers of The Royal Institute of Chemistry so as to make possible some comparison between the emoluments of members of the two bodies.

OCCUPATIONAL CLASSIFICATION

Members were asked to indicate their occupations by means of the reference letters listed in Table 2.

Table 2.—*Occupational classes.*

Reference letter	
	Employee in or under—
A	Industry (not nationalized)—including an executive director
	Nationalized Industry:
B	Transport (including Railways)
C	Coal
D	Gas
E	Electricity
F	United Kingdom Atomic Energy Authority
G	Scientific Civil Service
H	Other branch of central Government service
J	Local authority (not a teacher: cf. P, Q) or Public Utility (not nationalized)
K	Hospital (except posts more appropriately included in N)
L	Research Association
N	University or university college (including medical school). Not research student—see T
P	Technical College—including a Principal
Q	School—including a headmaster or headmistress
R	Other field of employment
S	Employer or Self employed
	Other category—
T	Student dependent on research or maintenance grant
U	National Service
V	Retired
W	Unemployed, if under retiring age for last employment

Table 3.—*Classification of returns by grade, age and occupation*

Occupational group/Grade	Age Group	Under 31			31–40			41–50			51–60			61 and over			All ages (men)			Women all grades	Total
		F	A	G	T	F	A	G	T	F	A	G	T	F	A	G	T	F	A	G	T		
A—Industry		—	—	125	364	489	42	419	196	567	75	98	—	173	47	18	—	65	8	3	—	11	172	683	470	1305	25	1330
B, C, D, E—Non-salaried Industry		—	—	13	24	37	10	57	55	122	10	72	—	82	5	2	—	7	—	—	—	—	25	156	96	277	4	281
F—U.K. Atomic Energy Authority		—	—	33	89	124	11	65	22	98	8	12	—	20	1	5	—	6	2	—	—	2	22	117	111	250	4	254
G—Scientific Civil Service		—	—	16	41	57	7	89	13	109	36	59	1	96	17	10	—	27	5	1	—	6	65	175	55	295	4	299
H, J—Other Government and local authority service		—	—	5	10	15	2	17	2	21	8	19	1	28	10	6	—	16	2	—	—	2	22	47	13	82	—	82
K—Hospital		—	—	4	7	11	6	22	2	30	6	10	—	16	2	1	—	3	—	—	—	—	14	37	9	60	4	64
L—Research Association		—	—	—	10	10	3	36	9	48	20	8	—	28	16	1	—	17	13	—	—	13	39	45	35	119	8	127
M—University		—	—	—	36	36	45	96	9	150	20	20	—	40	39	3	—	42	—	—	—	—	104	152	43	299	6	305
P—Technical College		—	—	—	38	38	8	121	18	147	23	43	1	67	15	19	—	34	5	5	—	10	51	223	70	344	6	350
Q—School		—	—	—	51	51	—	—	49	18	67	2	43	4	49	7	24	1	32	2	3	—	5	11	120	79	210	13	223
R—Other salaried post		—	—	1	56	57	—	41	16	6	22	4	3	—	7	3	1	—	4	2	—	—	2	9	20	10	39	5	42
Total		—	—	275	710	985	129	958	205	1292	242	332	7	581	160	90	1	251	39	12	—	51	570	1667	925	3162	77	3239
Self employed		—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	5	11	4	20		
Retired		—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	46	9	1	56		
Woman professionally employed		—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	9	29	39	77		
Research grants		—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	6	85	91		
National service		—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	8	8		
Unemployed		—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	3	4		
Retired		—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	4	2	2	8		
Total returns		—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	635	1724	1067	3426		

Fewer cards than usual (only eight) had to be excluded because of ambiguity or incompleteness. Members were given the option of signing the cards; it is gratifying to the two officers of the Institute to whom the data are personally confidential (Dr. H. R. Lang and Mr. N. Clarke) to be able to report that not only were about 95% of the cards signed but a number of members also sent letters to clarify points that might have been ambiguous. It is thereby possible to extract additional information that does not appear in this report but which will be of considerable value to the Executive Officers.

The number of returns in each grade, age group and occupational group is shown in Table 3. Once again the main table gives only the returns from men, and unless it is otherwise indicated the whole of this report relates only to men. In general the salaries of women members are below those of men of the same age and grade but the total number of returns from women is still too small to permit separate analysis.

SALARIES AND EMOLUMENTS

Members were asked to include in "salary" any bonus or share of profits or any allowance other than for expenses, but not to include an employer's contribution to a superannuation scheme. In addition they were asked to give separately any emoluments from professional work consistent with but not part of the salaried employment. The sort of work envisaged in this connection is book royalties, consulting work or examining by members of university staffs. It is, of course, arguable what kind of work (or how much of it) might be inconsistent with the salaried post but in practice no difficulty arises. Except for some teachers in universities, technical colleges and schools, additional emoluments are trivial and would not affect the broad picture presented in this report. The same procedure has been followed as in previous surveys. Additional emoluments have been included for teachers of all levels; however, in this report, the extent of these additional earnings is indicated—for Fellows and Associates only—in Table 4. It will be seen that more than one-third of Fellows in university posts earn more than £250 p.a. and about 15% of them earn upwards of £500 p.a. in this way.

Table 4.—*Additional emoluments of teachers.*

	None	*Less than £100*	*£100 –249*	*£250 –499*	*£500 –999*	*£1,000 and over*	*Total*
Universities							
Fellows	23	38	36	27	20	5	149
Associates	77	29	35	10	3	2	156
	100	67	71	37	23	7	305
Technical colleges							
Fellows	20	10	13	6	2	—	51
Associates	155	41	22	4	1	—	223
	175	51	35	10	3	—	274
Schools							
Fellows							
Associates	79	14	24	6	5	3	131

It was unfortunate that enquiry cards for this survey were sent out only a few days before the announcement of a back-dated increase in the salaries of university staffs. Some degree of ambiguity inevitably arose but most of the university returns were in terms of the old salaries. If a card stated that the new salary was quoted an adjustment has been attempted; any error introduced will hardly affect the picture here presented. In general, university salaries quoted refer to the *old* scales.

A more significant effect on the data presented was caused by an announcement on July 26, 1960 (when almost all the returns had been received) that salaries in the Scientific Civil Service for grades up to and including that of Principal Scientific Officer were to be increased by amounts up to about 12%, the increases being back-dated to October 1, 1958. A reference to the effect of this increase is made later.

VARIATION OF EMOLUMENTS WITH AGE

It has always been the aim of these reports to present a reliable broad picture of the financial rewards offered to professional physicists. For men over the age of, say, 35 years the variation of salary can be very great, especially in industry, and the presentation of mean salaries would be misleading. The only statistic presented is the median. In Figure 1 smooth curves are given for the variation of median salaries with age for the three grades. For comparison the 1956 curves are also given.

The increases in the median salaries since 1956 have been surprisingly uniform. There has been an upward shift of each curve combined with an apparent increase in the rate of increment. In so far as a single rate of increase can be given, a figure of between 20% and 25% for any given age would be a fair estimate for any of the three grades.

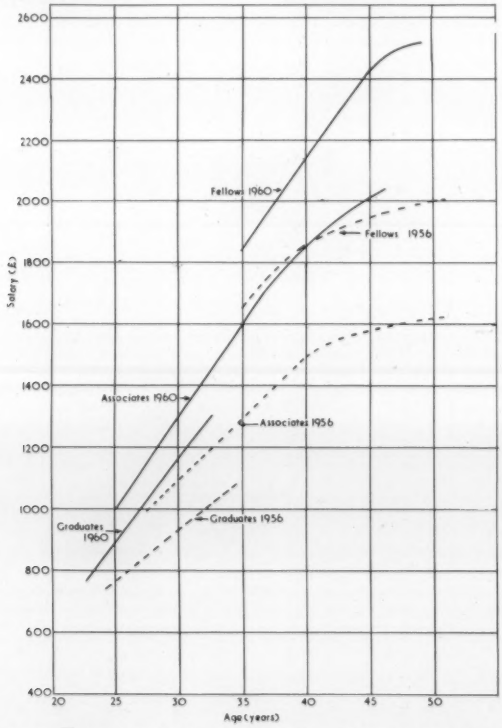

Fig. 1. Median Salaries of Fellows, Associates and Graduates of The Institute of Physics.

VARIATIONS OF EMOLUMENTS WITHIN GRADES

Table 5.—*Emoluments of Fellows*

	Aged under 41							*Aged over 41*						
	£1,000 –1,499	*£1,500 –1,999*	*£2,000 –2,499*	*£2,500 –2,999*	*£3,000 –3,999*	*Over £4,000*	*Total under 41*	*£1,000 –1,499*	*£1,500 –1,999*	*£2,000 –2,499*	*£2,500 –2,999*	*£3,000 –3,999*	*Over £4,000*	*Total over 41*
A—Industry	1	21	14	3	2	1	42	2	20	34	21	33	20	130
G—Civil Service ...	—	4	2	1	—	—	7	1	1	21	24	10	1	58
N—University	4	16	15	9	1	—	45	—	8	39	22	28	7	104
P—Technical College ...	—	3	4	1	—	—	8	2	16	18	3	4	—	43
All others	—	12	6	3	5	1	27	6	24	28	27	15	6	106
	5	56	41	17	8	2	129	11	69	140	97	90	34	441
All ages—employed ...								16	125	181	114	98	36	570
Self-employed... ...								—	—	1	—	—	4	5
								16	125	182	114	98	40	575

(*a*) Fellows

It is clear that the older men have shared in the general salary increase. Table 5 gives the incomes of Fellows of the Institute according to age group and the main occupational groups. For Fellows under the age of 41 the median salary is about £2,050 compared with about £1,700 in 1956; in this age group 53% earn more than £2,000 compared with 35% in 1956 and 13% in 1953. More than 20% earn over £2,500 compared with 11% in 1956 and 3% in 1953.

For the larger group of Fellows over the age of 41, the median salary is about £2,520, there being only about £50 difference in the medians of the groups aged 41-50 and over 51. In 1956 the corresponding figure was £2,025. In this group over 41 years, 82% earn over £2,000 compared with 51% in 1956 and 28% in 1953. There are 50% with salaries of £2,500 or more, compared with 25% in 1956 and 10% in 1953.

An interesting point is the close similarity in the median salaries of Fellows in the three main occupational groups. Although the small number of very large salaries (say, over £7,000) is largely confined to industrial posts, the average Fellow in Government service (where the returns cover an unusually narrow range about the median) or a university post can expect a salary similar to the average industrial salary.

Taking together Fellows of all ages and occupations, the median salary is now about £2,350. Table 6 gives the comparable figures for earlier years.

Table 6.—*Median salary of all Fellows.*

Year	*Median*
1951	£1,400
1953	£1,550
1956	£1,950
1960	£2,350

(*b*) Associates

About 40% of the returns from Associates refer to industrial posts and the curve for the median salary for Associates in Figure 1 follows closely that for industrial salaries. The main differences from that curve for other groups are as follows. The curve for the U.K. Atomic Energy Authority is £50-£100 above that for industry but the number of returns in this group is sufficient to define the curve only up to the age of about 35. The Scientific Civil Service curve is slightly below that for industry but the recent back-dated increment will have lifted the median for Government service above that for industry; the curve for younger Associates in university posts is decidedly below the industrial curve and will probably still be below it even with the new increments.

For the younger Associates (up to 30-32 years) by far the highest returns were from those employed in technical colleges; at the lower end of the age scale the median for this group was £200 above the industrial value and showed a very small spread. The curve for schoolmaster Associates is unfortunately not defined below the age of 32 when it is about £150 below the industrial level. The schoolmaster curve suggests a flattening to a ceiling value of about £1,600-£1,700 in the early 40s although 15 returns (12½%) showed incomes of over £2,000 p.a.

(*c*) Graduates

As in previous surveys the Graduate returns are still dominated by the industrial returns (just over 50%). As for Associates, the returns from technical colleges are the highest. Throughout the range shown for Graduates in Figure 1, technical college medians were £100-£150 above those of industry. Up to the age of about 30, schoolmasters compare well with industry. The lowest returns were for university posts.

Notes and News

Graduateship Examination 1961

The 1961 examination will be the last one under the old regulations. It was originally intended that the examinations under the new regulations would not be held until 1962, but in response to requests from a number of technical colleges it has now been agreed that Part I of the new examination will be held in 1961.

Copies of the new regulations and syllabuses are available on request.

Announcements of Symposia and Conferences

The Meetings Committee has decided that in future the notices containing detailed programme and application forms for participation in Institute and Society symposia and conferences shall be sent only to those members who request them on each occasion. Early preliminary announcements, giving an outline of the programme will be made in the *Bulletin*, and Members, Subscribers and Students are urged to make a regular habit of turning to the *Bulletin* each month to keep themselves informed of the many meetings being arranged. Small posters announcing these conferences will also be sent to research and development laboratories likely to be interested and announcements will also be sent to a limited number of periodicals (e.g. *Nature*).

This arrangement will apply to the meetings arranged by the Nuclear Physics and Solid State Sub-Committee of the main Meetings Committee and any similar sub-committee or special *ad-hoc* conference or symposia committee that it might set up. Members of Groups and Branches will continue to receive individual notices of their meetings.

Casual vacancy on Council

In accordance with Article 77 Council has appointed Professor C. C. Butler (*Associate*) to fill the vacancy on the first Council caused by the retirement, owing to pressure of work, of Professor B. Bleaney. The appointment is until September 30, 1961.

Royal Society Medals

The following awards of medals have been made by the President and the Council of the Royal Society :

The Rumford Medal to Dr. A. G. Gaydon, A.Inst.P., F.R.S., Warren Research Fellow, for his distinguished work in the field of molecular spectroscopy and particularly its application to the study of flame phenomena.

The Davy Medal to Professor J. M. Robertson, F.Inst.P., F.R.S., Gardiner Professor of chemistry and administrative head of the Chemical Laboratories in the University of Glasgow, for his distinguished pioneering work on analysis of crystal structure, especially of organic compounds.

The Hughes Medal to Dr. J. L. Pawsey, F.Inst.P., F.R.S., assistant chief of the Division of Radiophysics of the Commonwealth Scientific and Industrial Research Organization, Australia, for his distinguished contributions to radio astronomy both in the study of solar and of cosmic radio emission.

A Royal Medal is awarded to Professor A. C. B. Lovell, F.Inst.P., F.R.S., of the University of Manchester, for his distinguished contributions to radio astronomy.

The Institute and Society Awards and Appointments

The Council of the Institute and Society has made the following Awards :

The Duddell Medal to Dr. J. B. Adams, the Director-General of C.E.R.N. (the European Organization for Nuclear Research), for his leadership of that team.

The Charles Vrrnon Boys Prize to Professor A. W. Merrison of the University of Liverpool for his distinguished research in experimental physics.

The Charles Chree Medal and Prize to Dr. S. E. Forbush of The Carnegie Institution of Washington for his distinguished work on the cosmic radiation.

The Council has also made the following appointments :

Guthrie Lecturer: Dr. D. Shoenberg, F.R.S., of the Royal Society Mond Laboratory, Cambridge, has been appointed Guthrie lecturer for 1961.

Thomas Young Orator: Dr. H. H. Hopkins, F.Inst.P., of the Imperial College of Science and Technology has been appointed to deliver the Thomas Young Oration in 1961.

Conference on Physics of Polymers

The Institute and Society is arranging a conference on "Physics of Polymers" to be held at the University of Bristol, from 9 a.m. on January 10 to 1 p.m. on January 12, 1961.

Topics for principal sessions are:—

Statistics of Chain Configurations

Molecular Motions in Polymers

Fibre Structures and Crystallinity in Polymers

Irradiation Effects.

Further information and preliminary programs are available from The Secretary of the Institute and Society.

Reviews of Books

THE PRINCIPLES OF SCIENTIFIC RESEARCH

By Paul Freedman

Pergamon Press Ltd. : Oxford. Pp. xvii + 227. Price 25s.

This is the second edition of a book first published in 1948. According to the author's preface to the first edition, it was written primarily to help young men and women entering the field of research who " have still to learn how research should be done ". In the reviewer's opinion, neither they nor anyone else will receive much assistance from a perusal of this book.

The question could of course be raised whether a study of the principles of scientific method is, in any event, likely to help much in the actual day to day conduct of research—however interesting such studies are from a broad philosophical point of view. The question does not arise in the present instance, since nowhere in the book is there any adequate discussion of this subject.

The early chapters deal briefly with the history of the development of scientific method. Often the text consists of little more than a catalogue of scientific discoveries. Only those discoveries are noted which in the author's view were important for the development of scientific method. His treatment has some curious features. Thus, Mendeleeff's work on the Periodic Table seems to be regarded primarily as a great advance in methodology because of the use of the principle of classification ! Darwin's work on evolution, we are told, involved the application of a " new " principle in scientific research—" that of the value of an accumulated mass of systematized information as a means of establishing the validity of a new hypothesis ". The cell theory of Schleiden and Schwann is classed as an advance in methodology rather than as a great scientific discovery.

A chapter on Research and Philosophy continues the catalogue, and then proceeds in a very sketchy way to claim that the principles of Dialectical Materialism as enunciated by Marx and Engels, and also the philosophy of Whitehead, provide great help in the conduct of scientific research.

The chapters on " The Mental Approach " to research and on its planning and organization, which follow, contain a great number of trite and platitudinous remarks. The jejune flavour of the book may be illustrated by the following quotation from the section on " The Planning of Research ".

It is remarked that a scientist investigating thermionic or photo-electric phenomena " is certain to have to do some chemical work, and must therefore have at his disposal a chemical bench, a fume cupboard, a water-bath, diverse bunsen burners, retort stands, chemical wax, refractories, at least one gas or electric muffle furnace, a balance, a pump for filtering. a drying oven, a motor-driven stirrer and a ball-mill ".

The book is not to be recommended.

J. Ferguson.

SOME MATHEMATICAL METHODS OF PHYSICS

By Gerald Goertzel and Nunzio Tralli

London : McGraw-Hill Publishing Co. Ltd. Pp. xiii + 300. Price 66s.

This book was written with the express intention of collecting together those mathematical techniques which are used in quantum mechanics, acoustics, electromagnetic theory, reactor physics and other branches of theoretical physics. It has developed out of a course of lectures on Mathematical Methods of Theoretical Physics delivered by one of the authors for several years at New York University. The prerequisites for the course included differential equations and a first course in theoretical physics. Anyone attempting to read the book would be well advised to so equip himself first. This is a valuable account of useful techniques but only the more mathematically-minded physicist will benefit from a study of it. Linear operators, vector spaces, orthogonal functions, Fourier analysis and Green's functions are among the topics covered. A section on approximate methods includes perturbation methods, the Rayleigh variation principle and the Ritz method, and a very brief account of two numerical procedures for dealing with a vibrating string. The first part of the book is concerned with systems with a finite number of degrees of freedom and the second with those having an infinite number. The formal operator approach is used throughout. Each chapter concludes with a useful collection of exercises and a short bibliography.

Physicists with the necessary mathematical background will appreciate having this information presented in a single volume.

J. Crank.

RECOMMENDATIONS OF THE INTERNATIONAL COMMISSION ON RADIOLOGICAL PROTECTION: REPORT OF COMMITTEE II ON PERMISSIBLE DOSE FOR INTERNAL RADIATION

Oxford: Pergamon Press Ltd. Pp. xxxii + 233. Price 30s.

The history of the radiation hazard is a sad record of ignorance, folly and disaster. For 20 years after the discoveries of Röntgen and Becquerel, X-rays and radium were used freely with little regard for the consequences or even for the prompt and visible damage that they produced. By 1900 there were on record 170 cases of X-ray injury to doctors or patients. By 1922 more than 100 radiologists had died through over-exposure to radiation. For many years these warning signs were not heeded by the general public or by their medical advisers. Before the first world war, 150,000 Americans were using apparatus to produce radon solution for daily drinking. One physician in the United States had, by 1921, given 7,000 injections of radium in amounts from 10 to 100 micrograms.

Efforts to secure the safety of radiation workers began in the early 1920s with the formation of national committees in several countries. In the absence of units or instruments for the accurate measurement of ionizing radiations little was achieved until another decade had passed. The idea of a "tolerance dose" then began to emerge, by analogy with drugs and other toxic agents. This was an unfortunate concept; few drugs will kill a man after an interval of ten years or damage his remote descendants, but radiation (absorbed in sufficient quantity) will do both of these mischiefs.

During the second world war the atomic energy projects led to a great increase in the use of radiation and a corresponding improvement in safety standards. To-day it may reasonably be claimed that the hazards of occupational exposure to radiation are well controlled —though the newly-recognized risks incurred by the general public are still the object of anxious consideration.

This is the background to the work of the International Commission on Radiological Protection. The present volume, devoted to calculations and recommendations on the effects of internally-administered radioactive materials is important to those concerned with the medical uses of isotopes or the wider development of nuclear energy. It begins by setting maximum permissible levels for exposure to different types of radiation. The rules recommended here are complicated by dependence on the status of the exposed individual (as a radiation worker or a member of the general public), the parts of the body affected by the radiation and the time over which the dose is accumulated. Methods of calculating body dosage in terms of the physical and physiological properties of a radioactive material are explained in detail and used to prepare extensive tables giving maximum permissible body burdens for some 240 nuclides. Safety levels for concentrations in air and drinking water are also specified.

This book will be immensely useful as a work of reference, as a guide to the dangers of medical or industrial procedures with radioactive materials and as a sheet-anchor for those concerned with maintaining the public safety against accidents with radioactive materials.

J. M. A. Lenihan.

MICROWAVE TRANSMISSION

By J. C. Slater

New York : Dover Publications Inc. Pp. 309. Price $1.50.

This book first appeared in 1942 in the International Series in Physics published by McGraw Hill. No changes have been made in the text, apart from the correction of some minor errors. The present edition is produced as a paper backed book at a lower price, but the same type face is used as in the earlier edition.

The book discusses in detail the relation between transmission line theory based on ordinary circuit analysis, and the more accurate waveguide theory based on Maxwell's equations. Other chapters deal with radiation from antennae, and the coupling of coaxial lines and waveguides.

T. B. Rymer.

PROCEEDING OF THE FIFTH CONFERENCE ON MAGNETISM AND MAGNETIC MATERIALS

London: McGraw-Hill Publishing Co. Ltd. Pp. viiS + 419S. Price 77s. 6d.

The annual occasion of the publication of the Proceedings of the American Conference on magnetism is fast becoming a Moveable Feast, and the contents of this Report contains some 170 papers. For the first time a comprehensive alphabetical index is included so that the Proceedings are now not only very useful but also usable. The range of subjects covered by these papers should be sufficient to ensure that every worker in magnetism has a copy on his desk. In addition to the specialist articles there are a number of papers of rather wider interest: Dr. Conyers Herring discusses *d* electrons in transition metals in a readable fashion (as he says "in elementary language"), the optical properties of magnetic crystals are described by Dr. A. M. Clogston and there are two papers on the unexpected subject of the application of magnetism in medicine. One paper which though of a specialized nature, is particularly worthy of mention, by Fuller and Hale, describes the application of electron microscopy to the study of domain boundaries and includes a short but beautiful series of micrographs of a domain wall in motion.

R. S. Tebble.

INCOMPRESSIBLE AERODYNAMICS

Edited by Bryan Thwaites

London: Oxford University Press.Pp. xx + 636. Price 75s.

This is the latest addition to the series of books on fluid dynamics prepared at the suggestion of the Aeronautical Research Council. The first of these works, *Modern Developments in Fluid Dynamics* edited by S. Goldstein, was prepared in 1938 as an account of the advances made in the theory and experiment of the flow of a viscous fluid since the time of the introduction of Prandtl's boundary layer theory. In 1951 the Aeronautical Research Council suggested that the material of Goldstein's book should be brought up to date by the preparation of three new volumes. One of these is the book under review; the other two, on laminar boundary layers and on turbulence, have still to appear.

It should be said at once that both the scope and purpose of the present work differ from those of Goldstein's book. The latter has come to be recognized as a standard introduction to those branches of incompressible fluid dynamics which go beyond ideal fluid theory, whereas the former limits itself to those flows which are, in the words of its preface, "more or less closely related to the problems of the flight of aircraft."

There is one short chapter on the boundary layer (which is to be treated at length in the companion volumes). This is a very good summary of the main features and the determination of the more important characteristics such as skin friction and displacement thickness. Apart from one or two digressions, the

whole of the rest of the book is devoted to the steady inviscid flow, outside the boundary layer, past wings and axisymmetrical bodies.

The result of such specialization is an account which is both exhaustive and authoritative. It was prepared by sixteen collaborators, all of them well known in the field of aerodynamics. It is written for those aerodynamicists who want a book containing the results of fluid dynamics which are of direct practical utility in their field, omitting the frills which would make it more palatable to the general reader. The former will find it a valuable addition to their library.

W. CHESTER.

BASIC PRINCIPLES OF NUCLEAR SCIENCE AND REACTORS

By A. M. Jacobs, D. E. Kline, and F. J. Remick

London : D. Van Nostrand Co. Ltd. Pp. viii + 262. Price 49s.

This is a most useful book for anyone who has some knowledge of basic physics and simple calculus and wishes to be introduced into the mysteries of nuclear reactor science. The authors of such a work face two difficulties. On the one hand the processes of nuclear fission and the working of reactors are fairly mysterious even to the expert, on the other the basic facts of nuclear physics are not easy to explain to the reader at whom this book is aimed. There is therefore of necessity a great deal of statement of fact without proof which makes a logical development of the subject always difficult and at times impossible. In addition, the whole field bristles with what to the outsider appears a quite unnecessarily large number of specific symbols and technical terms, which in the absence of a glossary are difficult to deal with. An example of the superfluous is the statement " Probability, as used here, is just an alternate term for fraction ".

But on the whole the authors have done well and the industrious reader will profit greatly. After a perhaps too brief account of basic nuclear physics the book turns to the fission process and a consideration of criticality factors. There then follow excellent chapters on reactor characteristics and on special reactor systems and the book closes with chapters on radiological protection and on the uses of ionizing radiation. It should be noted that the book draws its illustrations exclusively from American experience. With this reservation it can be thoroughly recommended to the English reader.

L. R. B. ELTON.

ATOMIC THEORY FOR STUDENTS OF METALLURGY

By William Hume-Rothery

London : Institute of Metals. Pp. viii + 427. Price 50s.

The title of this well-known text book, now in its third edition, is too restrictive. For it can be read with profit and real enjoyment not only by students of metallurgy, but also by those of physics, and it is from their point of view that the book ought to be discussed in this *Bulletin*. It is notoriously difficult to present atomic theory in an unmathematical way and at the same time even students of physics need such a presentation to enable them to discern the physics through the mathematical thicket. Professor Hume-Rothery's treatment combines a minimum of mathematics with a maximum of explanation in a masterly way which is comprehensible and yet not without rigour. This is particularly so in his avoidance of the picture of electron orbits and in his insistence on the use of probability distributions instead.

But there is far more to the book than that. Physicists frequently seem to be satisfied with considering one atom at a time, and this is particularly so at the undergraduate stage. Here the student will learn of the physics contained in the theory of valency and of metals, so often dismissed in ignorance as mere chemistry or—worse—metallurgy. I remember Professor Bernal remarking recently that physicists would have to get used to the fact that metallurgy was now a science. No one who reads this book can doubt it. To give but one example of the kind of revelation that this book will yield to physicists—how many students really appreciate that the electron cloud around a free atom is often quite different from that around the same atom when bound in a solid ?

To add to this, the whole is written in a most felicitous style, and when it comes to the eradication of widely accepted errors, the author hits out with great force and, at the same time, great charm. But why are functions described as *gerade* and *ungerade* ? What is wrong with even and odd ?

L. R. B. ELTON.

GROUP THEORY IN QUANTUM MECHANICS

By Volker Heine

Oxford : Pergamon Press Ltd. Pp. ix + 468. Price 90s.

The mathematical theory of groups first became important to physics in analyzing the symmetries which could arise in the regular array of atoms and molecules in a crystal, thereby facilitating the classification of the different types of crystal. Of recent years it has become important again for essentially the same purpose. This time it is the symmetry properties of the Hamiltonian which are under consideration, and the way in which these symmetries are reflected in the wave functions.

This book develops both the basic theory of groups and the application to quantum mechanics at the level of a course for research students in physics or chemistry. The first three chapters develop the main ideas of group theory. After these the reader may proceed to whatever applications in the later chapters most interest him. These cover the theory of free atoms and ions; the structure and vibrations of molecules; solid state physics; nuclear physics; and relativistic quantum mechanics.

It must not be thought, however, that the book can be divided into two separate parts. The subject matter is in fact closely integrated. In the early chapters the basic ideas of group theory are illustrated by examples from quantum physics, some of the proofs of theorems being relegated to appendices, while many of the later chapters develop further properties of groups which are relevant to the applications discussed in the particular chapter.

Each chapter offers some problems for the reader to work out, ranging from simple drill examples illustrating the theory, to further applications and extensions of the theory.

Altogether this is a well thought-out book which should serve a useful purpose in the field for which it is written.

A. W. GILLIES.

SURFACE MICROTOPOGRAPHY

By S. Tolansky

London : Longmans, Green & Co. Ltd. Pp. viii + 295. Price 55s.

It is unusual for a scientist to take an established field of science, to discover new potentialities in it, and to make it so completely his own as Professor Tolansky has done. In the past twenty years he has carried the method of multiple-beam interferometry to new heights and he and his students have used it to examine many problems connected with surface structure.

This method is the subject of the present book, which deals solely with the work of Tolansky and his students ; almost all the references are to his published papers and students' theses. The theoretical basis is explained clearly and succinctly, and numerous special techniques are described. Then follow several chapters on particular results—topography of crystal faces ; cleavages and etchings ; oscillators ; deformation of metal surfaces ; and properties of diamonds. Each subject is lavishly illustrated with the beautiful photographs that we have come to expect from the author.

Those who are concerned with surface problems will find the book of great interest. It shows how such structures can be examined in great detail, and poses many problems of considerable importance ; it is not surprising that, with such a multitude of problems, many are still unsolved, and they are left as challenges to future workers in this field.

The book is beautifully produced and printed on "glossy" paper throughout. It suffers occasionally from lapses in punctuation and from odd expressions which probably are the author's own (for example, "such microflats have found considerable employ with us.'). But these are minor criticisms of a very handsome volume.

H. LIPSON.

HIGH ENERGY NUCLEAR PHYSICS

By W. O. Lock

London : Methuen & Co. Ltd. New York : John Wiley & Sons Inc. Pp. xi + 190. Price 18s.

For some years there has been no up-to-date introductory account of pion physics available, of the kind one would recommend to a research student to gain an overall picture of the field. Dr. Lock's little book fills this gap very well and he is to be congratulated on the amount of material he manages to get into such a small and therefore reasonably priced book.

Following two chapters on the properties of pions and on basic concepts (such as isobaric space), pion-nucleon scattering, photo-production of pions and production of pions in nucleon-nucleon collisions are discussed. There are also two chapters on nucleon-nucleus scattering (optical model) and nucleon-nucleon scattering (phase shift analysis and interpretation in terms of potentials).

The emphasis is always on the physical concepts, not on experimental or mathematical details. A phenomenological viewpoint is adopted throughout which centres around the fundamental role of the (3, 3)—resonance, representing almost the totality of our understanding in the field of pion physics. The brevity of the book of course affects the treatment. It has often been necessary to quote results rather than derive them. At times the presentation is very brief (e.g. the discussion of field quantization seems unlikely to provide an adequate level of understanding) or oversimplified (e.g. in the discussion of polarization effects in nucleon-nucleon scattering, the fact that these effects are strongly energy-dependent and, consequently, the usefulness of eqn. (6.31) very limited should have been mentioned). In many cases a more careful wording or the extra sentence would have clarified things greatly. But a critical student is not likely to be misled by these minor shortcomings.

The value of a book on a growing and as yet little understood subject depends on its being up to date. There are already several places where more recent information could usefully have been incorporated (judging from the dates of the references, there was a rather long delay in publication). It is to be hoped that the author and the publishers will not shirk the task of periodically issuing revised editions of this useful little book.

F. MANDL.

A

Nuclear Physics Conference

is to be held in

The University of Birmingham

April 17, 18 and 19, 1961

This Conference will be sponsored by The Institute of Physics and The Physical Society

It is proposed to devote sessions to the following:—

(i) γ-ray scattering

(ii) Low Energy Nuclear Reactions—Nuclear Models

(iii) Instrumentation and Machines

(iv) Nucleon-Nucleon and Nucleon-Nucleus High Energy Physics

Programmes and application forms will be available in mid-February from the Conference Secretary, Department of Physics, The University, Edgbaston, Birmingham, 15.

Forthcoming Institute and Society Meetings

Date	*Place*	*Speaker*	*Title and other details*	*Time*	*Branch or Group*
Dec. 2	**London** Headquarters	Dr. A. C. G. Menzies, F.Inst.P.	**Chairman's Address on Atomic absorption spectroscopy**	3.00 p.m.	Appl. Spectr.
Dec. 5	**Edinburgh** The University	Dr. R. A. Smith (*Royal Radar Establishment, Malvern*)	**Low noise amplifiers**	7.15 p.m.	Scottish
Dec. 6	**Glasgow** The University	Dr. R. A. Smith (*Royal Radar Establishment, Malvern*)	**Low noise amplifiers**	7.15 p.m.	Scottish
Dec. 7	**Sheffield** The University	Professor G. F. J. Garlick, F.Inst.P. (*University of Hull*)	**Luminescence and recombination radiation in semiconductors**	5.00 p.m.	Yorkshire
Dec. 7	**London** Headquarters	Mr. N. Clarke, F.Inst.P. (*The Institute of Physics and The Physical Society*)	**The international conference on physics education**	6.00 p.m.	Education
Dec. 8	**Liverpool** The University	Dr. L. R. Shepherd (*A.E.E., Winfrith*)	**Dragon project**	7.00 p.m.	Liverpool and North Wales
Dec. 8	**Birmingham** The University	Professor P. B. Moon, F.Inst.P., F.R.S. (*University of Birmingham*)	**X-ray spectroscopy**	6.30 p.m.	Midland
Dec. 9	**London** Headquarters	Mr. P. Popper, A.Inst.P. (*British Ceramic Research Association, Stoke-on-Trent*)	**Recent developments in ceramics**	6.00 p.m.	Non-Destructive Testing
Dec. 9	**Newcastle-upon-Tyne** King's College	Dr. O. S. Heavens, F.Inst.P. (*Royal Holloway College, London*)	**Masers in the optical and infra-red regions of the spectrum**	6.15 p.m.	North-Eastern
Dec. 9	**Bristol** The University	Mr. Thorold G. Jones, F.Inst.P. (*Atomic Energy Research Establishment, Harwell*)	**Gem stones**	7.00 p.m.	South-Western
Dec. 12	**Manchester** The University	Professor W. D. Wright (*Imperial College of Science and Technology, London*)	**The problem of the accurate measurement of colour and small colour differences**	7.00 p.m.	Manchester and District

The Register

ELECTIONS TO MEMBERSHIP

THE FOLLOWING ELECTIONS WERE MADE BY THE COUNCIL ON OCTOBER 4, 1960

An asterisk (*) indicates transfer from another grade

FELLOWSHIP of the Institute of Physics (4)

*Maclean, Donald John, B.Sc., Head of Soils Section, Road Research Laboratory, D.S.I.R., Harmondsworth, Middlesex.

*Morgan, Colyn Grey, M.Sc., Ph.D., Lecturer, University College of Swansea.

*Rose, Hyman, B.Sc., Ph.D., Chief Physicist, C. A. Parsons & Co. Ltd., Newcastle-upon-Tyne.

*Runciman, William Alan, D.Sc., Senior Lecturer, University of Canterbury, Christchurch, New Zealand.

ASSOCIATESHIP of The Institute of Physics (45)

*Absalom, Robert Major, Senior Experimental Officer, Atomic Energy Establishment, Winfrith, Dorset.

*Berry, Douglas William, Development Engineer, Hilger & Watts Ltd., London.

Bowles, Leslie Frederick, B.A., Physicist, English Electric Co. Ltd., Whetstone, Leicestershire.

Braden, Michael, B.Sc., Senior Scientist, British Rubber Producers Research Association, Welwyn Garden City, Hertfordshire.

Bridge, Noel Keith, B.Sc., Ph.D., Group Leader, British Rayon Research Association, Wythenshawe, Manchester.

Brown, Penelope Jane, M.A., Ph.D., Research Fellow, Cavendish Laboratory, Cambridge.

Campbell, Ian Douglas, B.A., M.Sc., Ph.D., Scientific Officer, Defence Standards Laboratory, Victoria, Australia.

Cohen, Adrian Victor, M.A., Ph.D., Principal Scientific Officer, Atomic Weapons Research Establishment, Aldermaston, Berkshire.

Crawford, Sheila Marion, M.A., Physicist, Imperial Chemical Industries Ltd., Dyestuffs Division, Blackley, Manchester.

*Grunbaum, Enrique, M.Sc., Director of Research in Electron Diffraction, University of Chile.

*Gunston, Mark Antony Richard, B.Sc., Microwave Development Engineer, English Electric Valve Co. Ltd., Chelmsford, Essex.

*Harper, Maurice Edward, Head of Vacuum Metallurgy Research Division, Edwards High Vacuum Ltd., Crawley, Sussex.

Harrison, Herbert Clifford, A.R.C.S., Formerly of Department of Civil Aviation, Melbourne, Australia.

*Higgins, John Christopher, M.A., M.Sc., Lecturer, The Northern Polytechnic, London.

*Hogg, Arthur, M.Sc., Senior Assistant, The United Steel Companies Ltd., Rotherham, Yorkshire.

*Hope, Charles Stewart, A.R.C.S.T., Physicist, Western Regional Hospital Board, Regional Physics Department, Glasgow.

*Hughes, Anne Florence, B.Sc., Physics Teacher, Newport High School, Monmouthshire.

*Innes, Robert, B.Sc., Ph.D., Research Engineer, Marconi's Wireless Telegraph Co. Ltd., Chelmsford, Essex.

Jeffrey, Zebulon Ross, B.Sc., Higher Experimental Officer, Weapons Research Establishment, Salisbury, South Australia.

*Jessop, Alan Michael, B.Sc., Ph.D., Research Officer, British Cotton Industry Research Association, Shirley Institute, Didsbury, Manchester.

*King, Derek Edwin Noel, B.Sc., Ph.D., Scientific Staff, The General Electric Co. Ltd., Research Laboratories, Wembley, Middlesex.

Knowles, John Ernest, B.Sc., Senior Physicist, Mullard Research Laboratories, Salfords, Surrey.

Langham, Edward Joseph, B.Sc., Ph.D., Physicist, Central Electricity Generating Board, Leatherhead, Surrey.

*Leach, Donald Frederick, B.Sc., Physicist, The British Jute Trade Research Association, Dundee.

*Levy, Anthony, B.Sc., Ph.D., In charge of Physics Research Section, Commonwealth Research Laboratories, Broken Hill PTY, New South Wales, Australia.

Mayer, Peter Alan, B.Sc., Assistant Lecturer, South-West Essex Technical College, London.

Muirhead, Edmund G., M.Sc., Ph.D., Lecturer, University of Melbourne, Australia.

Peters, Basil, B.A., Assistant Head of Electronic Department, Fairy Aviation Ltd., Heston, Middlesex.

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Stewart, Alan Lawther, B.Sc., Ph.D., University of Belfast, Northern Ireland.

Squires, Terence Leighton, Research Unit in Radiobiology, Mount Vernon Hospital, Northwood, Middlesex.

Fifty-three Students and one Subscriber were also admitted.

The Journals

PRINCIPAL CONTENTS OF THE NOVEMBER, 1960, ISSUES

British Journal of Applied Physics : Volume 11, No. 11

Summarized proceedings of a conference on the borders of X-ray analysis—Reading, April, 1960.

The Annual Spring Conference of the X-ray Analysis Group of The Institute of Physics was held at the University of Reading on April 8 and 9, 1960. The papers and discussions ranged over a number of subjects including neutron and electron diffraction, X-ray emission spectroscopy and X-ray micro-analysis.

X-ray microscopy of beryllium. By J. Sawkill and D. R. Schwarzenberger.

The point-projection X-ray microscope has been used to study a variety of beryllium specimens, ranging from single crystals to finely-polycrystalline metal containing inclusions. The highly divergent beam of X-rays from a source 1μ in diameter gives, on the same photograph, a microradiograph of the specimen with a resolution of 1μ and a divergent beam diffraction pattern. Together these can give information about the distribution of heavier elements or cracks in the beryllium, the variation in perfection of the crystal lattice and, with a single crystal, the orientation and lattice parameters of the specimen.

Some electrical and surface properties of sintered nickel matrix cathodes. By R. W. Fane, A.Inst.P.

Measurements of the work function of nickel matrix cathodes yield values in the region of 1 eV. Schottky plots are found to agree with theory provided the cathode surface is polished. Deviations from the image law at low field strengths may be explained using patch theory with suitably chosen parameters. The results of surface field determinations indicate a very small degree of coverage of the nickel grains by alkaline earth metals or oxides.

Production of resonance radiation in discharge tubes of non-circular cross-section. By M. A. Cayless, A.Inst.P.

The theory of d.c. low-pressure metal-vapour rare-gas discharges is developed, for the cases of simple one-stage and simple two-stage ionization, in a manner which enables the performance of a discharge in a tube of any given cross-sectional shape to be derived from that of an " equivalent " discharge in an " equivalent " tube of circular cross-section. The latter can be obtained from a more detailed investigation of the discharge in a circular tube.

It is shown that the discharges are capable of producing substantially more resonance radiation per unit length at a given efficiency in tubes of a " flattened " cross-sectional shape, than in tubes of a circular cross-sectional shape, particularly when there is a narrow, or waisted, middle section. Multi-stage ionization ultimately restricts the extent to which this improvement can be carried to aspect ratios of about 3 : 1.

Contrast of electron micrographs. By J. S. Halliday, F.Inst.P. and T. F. J. Quinn, Grad.Inst.P.

The variations of contrast in electron micrographs of amorphous films, with film thickness, electron accelerating voltage and objective aperture angle, are discussed; elastic and inelastic electron scattering and the possibility of plural

scattering are taken into account. Experimental results, obtained with vacuum-evaporated iron films, confirm a formula of the type first proposed by Hall. However, the contrast is about four times smaller than predicted, using scattering cross-sections based on Lenz's data. Results for other materials, obtained by previous workers, indicate similar discrepancies. At present, the likeliest explanation appears to be a theoretical underestimation of the scattering into angles smaller than 10^{-3} : rad. The limitations of contrast measurements for assessing specimen thickness or constitution are discussed, and a new criterion for replica and shadowing materials suggested.

Study of background structure in platinum/carbon shadowing deposits. By D. E. Bradley.

The aggregation of metal shadowing deposits into small crystallites causes a background structure well known to electron microscopists. A different structure has been found to occur with amorphous shadowing materials. The paper describes the form of the structure and it is shown that the main cause is the hydrocarbon deposit formed on surfaces in the evaporating unit. The effect of the statistical distribution of the shadowing atoms on the ultimate resolution obtainable is discussed.

Smoke density integrator. By R. M. Storey, Grad.Inst.P.

A simple instrument is described which both indicates and integrates the optical density of smoke in the range 0 to 1·0 optical density per foot. It consists of a detector unit exposed to the smoke and a remote control unit containing the indicator and integrator. A barrier-layer photocell, mounted within the detector unit, is loaded to give a logarithmic light intensity-voltage characteristic, so that a smoke obeying the Beer-Lambert law gives rise to a linear decrease in cell voltage with increasing optical density. Integration is achieved by means of a capacitor charged by the out-of-balance current of a self-rectifying a.c. bridge, in which the impedence of one arm is controlled by the photocell output. The overall stability over twenty-four hours is of the order of $\pm 6\%$.

Fifth order spherical aberration of magnetic lenses. By G. D. Archard.

Knowledge of the fifth order spherical aberration of magnetic lenses is required in order to show how much error is left when third order aberration is corrected. This is found theoretically for lenses of the bell shaped field type. It is found that, for lenses of moderate strength, third and fifth order coefficients are numerically very similar.

Selected-area diffraction in the electron microscope. By R. Phillips, A.Inst.P.

A direct demonstration is given of the error in the area contributing to the recorded diffraction pattern, which arises from use of the incorrect objective focal length in micro-diffraction experiments in the electron microscope. The effect of errors in the final intermediate lens setting is also discussed, and reproducibility of the camera constant λL in selected area diffraction is investigated.

Agar* has emphasized that a certain operational procedure has to be closely followed, if a selected area diffraction pattern in a three-stage electron microscope is to come solely from the area defined by the selector aperture under magnified image conditions. It is the purpose of this paper to demonstrate directly the contributions which may occur from an annulus outside the image of the aperture, due to incorrect excitation of the objective lens, and to comment on another important aspect of selected area diffraction—the reproducibility of λL.

*Agar, A. W. *Brit. J. Appl. Phys.*, **11**, pp. 185-189 (1960).

Wear of the hard and soft phases in cobalt-bonded tungsten carbide. By J. Golden and G. W. Rowe, A.Inst.P.

It has previously been widely accepted that the normal wear pattern of cobalt-bonded tungsten carbide is a steady attrition of the soft matrix, leading to occasional loosening of hard carbide grains. This hypothesis seems to have been based on visual examination of autoradiographs of copper wire drawn through radioactive tungsten carbide dies.

The present experiments show that autoradiographs of this type, having a steady general level of blackening with local dense spots superimposed, are obtained if the copper surface is not sufficiently well prepared. On smooth surfaces uniform autoradiographic density is observed. Detailed measurements of the former type of autoradiograph have been made, showing first the short-lived tungsten activity and finally the long-lived cobalt activity. These refute the suggestion that the spots are carbide grains and that the general level is cobalt. The composition of the wear deposit in both is the same, and corresponds closely to the initial composition of the bonded carbide. The revised picture of steady continuous wear of both phases concurrently, accords with other experimental evidence quoted.

Journal of Scientific Instruments : Volume 37, No. 11

Apparatus for measurement of sorption of reactive condensable vapours up to 350°C. By R. M. Barrer and S. Wasilewski.

An apparatus for the measurement of sorption of reactive, condensable vapours at temperatures up to 350°C and pressure range 0·1–760 mm of mercury is described. It is composed essentially of a wholly enclosed Pyrex-glass balance system, incorporating a silica spring balance, a sensitive platinum resistance thermometer and a spiral pressure gauge; the whole unit being surrounded by electric furnaces. The pressure and temperature measurement and control are also described. The amount sorbed can be measured with accuracy to 0·03 mg; pressure to at least 0·05 mm of mercury; temperature to 0·01°C.

Lens mass-spectrometer leak detector. By D. Cossutta, and W. Steckelmacher, F.Inst.P.

A new mass-spectrometer leak detector was investigated based on the use of an iron-shrouded axially symmetrical magnetic lens for focusing ions in the low mass range. By taking precautions to keep the hydrogen background at a low and stable level (by the use of a mercury-vapour pump, liquid-air traps and clean construction) it was possible to use hydrogen as a search gas. Leaks of 5×10^{-10} Torr litre/s corresponding to an indication of a change in ion current reading of about 3×10^{-13} A (for hydrogen) were consistently detected with an almost instantaneous response when testing equipment of a few litres volume using either hydrogen or helium as search gas. Some measurements of the mass spectrum obtained with this instrument are given. A very reliable and convenient version of a compressed-powder leak is also described.

Apparatus for the floating-zone refining of gallium arsenide. By F. A. Cunnell and R. Wickham.

The design and operation of equipment to purify and to grow single crystals of gallium arsenide are described. Features of the design include a demountable quartz system, adjustment of the relative position of the ends of the gallium arsenide rod during operation, excellent visibility, a traversable heater system and close control of the arsenic pressure in the tube. The latter feature has reduced the problem of ejection of molten material from the zone found in previous work.

Rapid counter for small particles in suspension. By J. B. Cornwall, and R. M. Davison.

Equipment based on a photoelectric detection method is described which has been designed for counting apple cells (approximate size distribution 70-500 μ length) but which may be used with any reasonably opaque particles of suitable size which can be held in suspension in a clear low-viscosity liquid. The accuracy of a single run is about ±3% including sampling errors. This error may be reduced by averaging several samples.

Digito-analogue computer for solving linear simultaneous equations and related problems. By E. V. Krishnamurthy.

This paper describes Lilavati model III, a digito-analogue computer for solving simultaneous and secular equations by a variety of iterative processes. Unlike the other computers in this field, multiplication is carried out by using Ohm's law and addition by null methods. The familiar Kelvin-Varley slide forms the basic circuit of the computer. This, in addition to simplifying the number of components involved in the computer, provides a method of feeding in and taking out the data as numbers, correct to three significant figures. An accuracy of between one and two parts in a thousand is readily obtainable.

Inexpensive graph plotter for five-track paper tape. By L. Molyneux and E. E. Schneider, F.Inst.P.

The device will produce a graph from data in the form of five-track paper tape. The rate of plotting is 20 points per minute at an accuracy of up to one part in 1000. Apart from a standard ten-millivolt potentiometric recorder and tape reader, the device requires 21 transistors, 2 valves and 22 relays.

Measurement of the optical thickness of absorbing specimens with the three-beam interferometer. By P. Hariharan, A.Inst.P. and D. Sen.

A simple modification of the three-beam interferometer is described which permits measurements of the optical thickness of absorbing specimens with a high degree of accuracy.

Low-compliance diaphragm-capacitance gauge for measurement of liquid pressures of the order of 1 in. water. By A. S. Lodge.

The construction of a compact "diaphragm-capacitance" gauge suitable for pressure measurement in viscous liquids is described. Sensitivities in the range 1 to 12 pF/in. water are obtained by using different diaphragm units, and the overall zero stability is about 0.002 in. water over a few hours. The response time is about 5 s when the gauge is filled with a 50 P liquid and the outlet hole is 0.5 mm in diameter and 2 mm in length.

Instrument for the measurement of specular reflectivity of bright metal surfaces. By B. A. Scott.

A simple modification of the gloss head for painted surfaces, described in Defence Specification DEF/1053 (Method 11), enables it to be used for the measurement of the surface quality of bright anodized aluminium in terms of specular reflectivity. The instrument has a high sensitivity and readily discriminates between surfaces of differing appearance. Good reproducibility between two instruments after modification, and satisfactory correlation with visual assessments of surface quality, have been obtained. The instrument should prove useful for the evaluation of bright finishes on other metals, but is not suitable for matt or highly diffusing surfaces.

Papers accepted for publication in *Proceedings of The Physical Society*

The range-energy relation for high energy μ-mesons. By F. Ashton.

The range-energy relation for μ-mesons with energies up to 1,000 GeV has been studied by comparing the sea-level energy spectrum of cosmic rays with the underground depth-intensity curve. No significant divergence from accepted theory has been found.

The thermomagnetic behaviour of cobalt ferrite. By L. F. Bates and A. J. Pacey.

The surface domain structure of a cube-textured 3% silicon-iron sheet was examined by the colloid technique. The patterns observed on most grains were typical of those previously reported on (100) surfaces in the single crystals, i.e. most grains contained two easy axes of magnetization in the surface, and usually one of these was parallel to the rolling direction of the sheet.

A new band-structure pattern was found, and by comparison with similar patterns on a single crystal was thought to be associated with bulk strain in the material.

Energy Transfer in Organic Systems. III. Solute-solute transfer in liquid solutions. By J. B. Birks and K. N. Kuchela.

Solute-solute intermolecular energy transfer has been studied in the ternary solution system toluene-TP (*p*-terphenyl)-TPB (1,1′, 4,4′-tetraphenylbutadiene) with a TP concentration of $2{\cdot}17 \times 10^{-2}$M, and TPB concentrations from $1{\cdot}5 \times 10^{-6}$M to 6×10^{-3}M, using excitation wavelengths from 285 mμ to 365 mμ.

The behaviour is described quantitatively by competition between radiative transfer, which predominates up to 10^{-4}M, and non-radiative dipole-dipole transfer, which becomes important at higher concentrations. The observed radiative transfer agrees with that predicted from the TPB absorption and emission spectra, and depends on the solution thickness. The observed dipole-dipole transfer corresponds to a critical transfer distance $R_0 = 42{\cdot}2$Å, compared with a theoretical value of $R_0 = 42{\cdot}5$Å, indicating that molecular diffusion and TP excitation migration have a negligible influence on the transfer process, which is single-step.

The bearing of the results on the choice and design of organic scintillator systems is briefly discussed.

The polymorphism of thallium and other halides at low temperatures. By M. Blackman and I. H. Khan.

Thin layers of caesium, rubidium and thallium halides have been evaporated on to amorphous bases at low temperatures, and examined by electron diffraction. All the caesium halides examined, as well as thallium chloride and thallium bromide, showed both the rocksalt structure as well as the normal caesium chloride structure. In general the abnormal structure gave the weaker pattern which decreased in intensity as the layer was heated and disappeared before room temperature was reached. Thallium iodide showed a caesium chloride structure at low temperatures changing to the normal orthorhombic form only in the neighbourhood of room temperature. The rubidium salts showed a rather persistent broad ring pattern at low temperatures in addition to the normal rocksalt rings. The diffuse ring pattern is consistent with a caesium chloride structure for the rubidium halides.

Paramagnetic resonance spectrometry at zero magnetic field. By G. S. Bogle, H. F. Symmons, V. R. Burgess and J. V. Sierins.

The need for direct measurements of paramagnetic resonance absorption spectra in zero magnetic field is discussed. Two

spectrometers have been built which together cover the range of 8 to 18 Gc/s ; with one of these a spectrum is recorded over a range of nearly 6 Gc/s in a time of two minutes with a sensitivity sufficient to detect about 10^{17} Fe^{3+} ions at 80°K. Polycrystalline samples may be used, and examples are shown of the spectra of a dilute ferric chelate compound. A technique is described for obtaining the absorption line shape free from the effects of the associated anomalous dispersion.

Air bubbles in ice. By A. E. Carte.

The opacity of ice formed from water containing dissolved air is due to the presence of bubbles of air in the ice. Both bubble concentration and sizes were found to depend on the rate of freezing. Bulk water saturated with air at 0°C was found to freeze into ice containing about six bubbles/mm^3 when freezing proceeded at 0·5 mm/min and 300/mm^3 at a rate of 5 mm/min. Bubbles were formed at the ice-water boundary when the concentration of dissolved air reached a critical value which, for rates of freezing greater than 2 mm/min, corresponded to a supersaturation ratio of 30. Agitation of the water could prevent the critical concentration from being attained and clear ice then formed.

Other factors which influenced bubble concentrations and sizes were the amount of dissolved air, pressure, thickness of the layer of water ahead of the growing ice and escape of bubbles by buoyancy.

The magnitude and extent of the air concentration gradient ahead of the ice were estimated from theory.

Bubbles in ice were found to change shape with time, particularly when under the influence of a temperature gradient.

The reaction $^{51}V(\gamma,\alpha)^{47}Sc$ and some remarks on (γ,α) reactions. By J. H. Carver.

The $^{51}V(\gamma,\alpha)^{47}Sc$ reaction has been studied using induced radioactivity techniques up to gamma-ray energies of 32 Mev. The cross section has a maximum value of 0·95 mb at an energy of 22 Mev and an integrated cross section to 32 Mev of 12 ±2 Mev-mb. The statistical model gives a satisfactory interpretation of the ratio of the $^{51}V(\gamma,\alpha)$ cross section to the $^{51}V(\gamma,n)$ cross section measured by Goldemberg and Katz (1954). It is probable that this interpretation can be applied to the (γ,α) yields from other middle-weight nuclei but it is not appropriate for the heavy nuclei ($Z > 50$). It is suggested that the roughly constant (γ,α) yields observed in the heavy nuclei may arise from direct electric dipole interactions with preformed " alpha-particles " in the nuclear surface.

Absence of Doppler shift for gamma-ray source and detector on same circular orbit. By D. C. Champeney and P. B. Moon.

An experiment is described showing that for a source and absorber of ^{57}Fe placed at opposite ends of a rotor the Mössbauer absorption is unaffected by rotation. This is contrary to the situation with the source at the centre when relativistic effects cause a frequency shift between source and absorber.

Neutron scattering from a liquid on a jump diffusion model. By C. T. Chudley and R. J. Elliott.

The incoherent inelastic scattering cross sections of slow neutrons from liquids is calculated using a simple model in which the liquid is assumed to have appreciable short range order in a quasi-crystalline form. Diffusive motion takes place in large discrete jumps, between which the atoms oscillate as in a solid. The model predicts a definite, easily calculable cross section which is not dominated by diffusion effects as when continuous diffusion is assumed, but shows a characteristic variation with angle which could be looked for experimentally. The related pair correlation functions are dominated at small r and t by vibrational effects. Although simple and extreme the model explains several aspects of the observations of Brockhouse and Pope (1959) and others. A brief discussion of the coherent scattering cross sections for the model although explicit formulae are not obtained.

Upper limits for the radiative capture cross sections of Al^{27} and P^{31} for O^{16} ions. By R. F. Coleman, D. E. Herbert and J. L. Perkin.

The radiative capture cross sections of Al^{27} and P^{31} for O^{16} ions with energies a few MeV above the expected thresholds for these reactions (~ 30 MeV) have been found to be $\leqslant 0{\cdot}2$ and $\leqslant 18\mu b$ respectively. Activation methods were used and care was taken to avoid errors due to impurities in the targets and the recoil into the targets of reaction products from elsewhere in the irradiation assembly.

A calculation based on the statistical theory of the compound nucleus predicts a cross section of $2\mu b$ for the capture in aluminium of O^{16} ions at the energy used in these experiments. Various possible reasons for this overestimation of the cross section are discussed.

Internal conversion of ^{141}Ce. By J. R. Cook.

The K conversion coefficient of the 141 K.e.v. gamma ray of Ce^{141} has been measured by a scintillation spectrometer as $\cdot 42 \pm \cdot 01$. This indicates that the radiation is probably electric quadruple.

Moving striations and anode spots. By J. R. M. Coulter, N. H. K. Armstrong and K. G. Emeleus.

An experimental study has been made of boundary conditions at the positive end of positive columns in neon which were traversed by waves of ionization (moving striations) proceeding towards the Faraday dark space. The striations were generated from small anode spots, which oscillated with increasing amplitude until they became detached from the anode. Closely similar processes took place at the negative end of a capillary tube when the discharge was passed through the capillary into a wide tube. A few typical time-resolved photographs of the oscillations have been reproduced to illustrate the nature of the phenomena and their dependence on pressure and current, and possible causes of the oscillations are discussed briefly.

The Hartree perturbation method for helium. By A. Dalgarno and J. M. McNamee.

The Hartree perturbation method is used to calculate the dipole polarizability, the electric field at the nucleus, the quadrupole polarizability and the nuclear shielding factor of helium using a 12-term representation of the unperturbed Hartree wave functions. It is pointed out that the method yields lower bounds for the dipole and quadrupole polarizabilities. The absolute error in the predicted values of any of the quantities is less than 4·3%.

A perturbation-variation calculation of eigenvalues. By A. Dalgarno and A. L. Stewart.

A variational method, based upon perturbation theory, is used to calculate the eigenvalues of the helium sequence. With a trial wave function containing essentially only one variable parameter, the resulting errors range from 0·2 eV for H^- to 0·01 eV for Ne^{8+}.

The $^{58}Ni(d,p)^{59}Ni$ and $^{60}Ni(d,p)^{61}Ni$ reactions. By A. W. Dalton, G. Parry, H. D. Scott and S. Swierszczewski.

In the present investigation, targets of natural nickel and isotopically pure ^{60}Ni were bombarded by deuterons with energies 8·9 MeV and 8·6 MeV respectively. From the resulting proton energy spectra a number of angular distribution measurements have been made for the $^{58}Ni(d,p)^{59}Ni$ and $^{60}Ni(d,p)^{61}Ni$ reactions and spin and parity assignments made to states of ^{59}Ni and ^{61}Ni. The results have also been compared with the gross structure peaks in the proton spectra recently reported by Schiffer, Lee and Zeidman.

Variation of photovoltaic response with magnetic field for a germanium p-n junction. By W. Dunstan.

Measurements are described of the variation with magnetic field of the open-circuit voltage of a germanium p-n junction photocell, the illumination being parallel to the junction plane,

and the field perpendicular to the illumination. The effect depends on the orientation of the field, vanishes when the latter is less than about 0·1 weber m^{-2}., and is proportional to illumination. A fairly complete discussion of the operation of the coil is attempted, both with and without field ; a partial explanation of the results is obtained.

The isobaric triplets in the nuclear 2p-shell and the charge independence of nuclear forces. By W. M. Fairbairn

The positions of the lowest lying $T = 1$ levels in the 2p-shell nuclei with $T_3 = 0$ are calculated from the experimental positions of the ground states of the nuclei with $T_3 = +1$ and the energy differences between the ground states of the nuclei with $T = \frac{1}{2}$. Coulomb forces are considered as a perturbation in the shell model and it is shown that, apart from small terms which depend on symmetry, the method is equivalent to that used by Wilkinson (1956). The corrections due to symmetry are of the same order of magnitude as the significant differences which Wilkinson found between the experimental and the calculated positions of the $T = 1$, $T_3 = 0$ levels, and when these corrections are included the differences are no longer significant. The energy shift due to the charge dependence of nuclear forces caused by the pion mass difference is calculated and is shown to be appreciable. There is good agreement between theory and experiment for the isobars with $A = 14$.

Diffusion narrowing of nuclear magnetic resonance in aluminium and copper. By C. P. Flynn and E. F. W. Seymour.

An apparatus has been developed by means of which nuclear resonance signals have been observed at temperatures up to 1300°K. The variation of the line shape and width of the Cu^{63} resonance at high temperatures is found to follow quantitatively the predictions of Eubo and Tomita for motional narrowing. In conjunction with the theoretical value of the frequency factor D_∞ (0·28 $cm^2 sec^{-1}$) in the expression $D = D_\infty \exp(-E/RT)$ for the coefficient of self-diffusion, the results yield a value 48·1 ± 0·9 kcal.$mole^{-1}$ for the activation energy for self-diffusion in copper, in agreement with the results of the most recent radio-tracer measurements. A similar change in shape and width of the Al^{27} resonance cannot be used to determine the activation energy in aluminium because of the presence of a line-broadening mechanism of uncertain origin. The data are not inconsistent, however, with the theory and the known activation energy of about 31 kcal.$mole^{-1}$.

The elastic scattering of electrons and positrons by hydrogen atoms. By A. E. Kingston and B. G. Skinner.

The expression for the differential cross section obtained from the second Born approximation by including only terms to the third order in the interaction energy is employed to calculate the differential and total cross sections for the elastic scattering of electrons and positrons by hydrogen atoms. Allowance is made for both distortion and polarization by evaluating the terms which correspond to transitions through the 1s, 2s and 2p intermediate states. It is found that for electrons with impact energies below 100 eV the effect of distortion and polarization is to increase the total cross section appreciably above the first Born cross section. For positrons, distortion and polarization decrease the total cross section.

The irreversible change of magnetization produced in 'square loop' ferrites by pulsed magnetic fields. By J. H. Knowles.

A core of square loop ferrite was examined under pulse magnetization conditions. Starting from romanence the irreversible change of magnetization produced by a series of very short pulses was measured by a ballistic galvanometer method. The results were interpreted on the basis of a domain wall model, which enabled an estimate to be made of the ratio of the time spent by the walls in reversible motion to the time spent in irreversible motion. From this ratio was deduced the average number of times that the domain wall energy passed through a maxima during the course of a magnetization reversal. The result so obtained, twenty-five, agreed well with that obtained by an independent method, due to Néel.

Scattering cross-sections of gamma radiation. By V. Lakshminarayana and Swami Jnanananda.

Total cross-sections of gamma rays from sources Cobalt-60, Scandium-46, Caesium-137, Chromium-51 and Cerium-141 in elements Graphite, Aluminium and Copper are determined using a scintillation spectrometer of good figures of merit and modified narrow beam geometry. The values of total scattering cross-sections are obtained by subtracting the theoretical values of photo-electric and pair cross-sections from the total experimental values. For energies greater than 662 Kev good agreement is observed between theoretical and experimental values of total scattering cross-sections while for energies 320 Kev and 145 Kev definite deviations are observed. The deviations are ascribed to the overestimation of total scattering cross-section by the use of atomic charge distribution predicted by Thomas-Fermi model.

Positronium formation in helium. By H. S. W. Massey and A. H. Moussa.

The cross-section for formation of positronium on impact of a positron with a normal helium atom is calculated by Born's approximation for positron energies up to 125 e. volts. As judged by the size of the maximum cross-sections obtained at positron energy of 27 e. volts, the coupling between elastic scattering and positronium formation is far from weak. This suggests that virtual formation of positronium may play an important part in the elastic scattering of slow positrons by helium atoms. The coupled equations for dealing with this effect are derived.

Activation cross sections with 14 MeV neutrons. By S. K. Mukherjee, A. K. Ganguly and N. K. Majumdar.

Some activation cross sections have been measured for the elements Na, Al, Sc, Cr, Cu, Ag and Bi using 14·8 MeV neutrons from the (DT) reaction. The cross-section values with their experimental errors are as follows:—

$Na^{23}(n,p)$ Ne^{23} 29 mb ± 10%, $Na^{23}(n,\alpha)$ F^{20} 222 mb ± 10%, $Al^{27}(n,p)$ Mg^{27} 77 mb ± 10%, $Sc^{45}(n,2n)$ Sc^{44m} 149 mb ± 15%, $Sc^{45}(n,2n)$ Sc^{44} 179 mb ± 15%, $Sc^{45}(n,\alpha)$ K^{42} 63 mb ± 15%, $Cr^{50}(n,2n)$ Cr^{49} 32 mb ± 10%, $Cr^{52}(n,p)$ V^{52} 105 mb ± 10%, $Cu^{65}(n,p)$ Ni^{65} 29 mb ± 10%, $Ag^{107}(n,2n)$ Ag^{106} (8·2 days) ~6500 mb, $Ag^{107}(n,2n)$ Ag^{106} (24 min.) 662 mb ± 10%, $Ag^{109}(n,2n)$ Ag^{108} 833 mb ± 10%, $Ag^{109}(n,p)$ Pd^{109} 2·7 mb ± 20%, $Ag^{109}(n,\alpha)$ Rh^{106} 12 mb ± 25%, $Bi^{209}(n,p)$ Pb^{209} 0·7 mb ± 15%, $Bi^{209}(n,\alpha)$ Tl^{106} 0·6 mb ± 15%. The cross-sections were measured in relation to 556 mb for the cross section of $Cu^{63}(n,2n)$ Cu^{62} and 117 mb for the cross section of $Al^{27}(n,\alpha)$ Na^{24} reactions. It has been found that the (n,x) cross section values follow more or less the empirical curve given by Blosser *et al* (1958).

A thermal motion effect in the electron spin resonance of a free radical in solution. By Dr. J. G. Powles and Mr. M. H. Mosley.

The electron resonance hyperfine triplet at 9·5mm wavelength of the peroxylamine disulphonate ion has been measured in a series of solutions of water and glycerol from 20% to 72%, glycerol by weight and over a temperature range from −46°C to 65°C. There is a temperature and solution dependent broadening which affects the individuals of the triplet differently. The high field line is broadened first with falling temperature. The effect is thought to be due to the motionally attenuated anisotripoc electron-nuclear interaction. The anisotropic interaction is estimated to be comparable with the isotropic one. The anisotropy of the g factor, $\Delta g/g$, is 2×10^{-3}. These parameters allow the prediction of a static spectrum of the ion in agreement with experiment (Weisamann and Banfill 1953). The effect of thermal motion of the ion is shown by the close relation between the value and tempera-

ture dependence of the thermal reorientation correlation frequency and the variation of the electron resonance signal with temperature and nature of the solvent.

Molecular motion in liquid toluene by proton magnetic resonance relaxation. By Dr. J. G. Powles and Mr. D. J. Neale.

Measurements are reported of the proton spin lattice relaxation time for both the methyl and ring protons in liquid toluene over a wide temperature range by recovery from saturation of the high resolution signal. The two sets of protons relax independently and show a very different dependence on temperature. The results are interpreted in terms of a complex motion of the toluene molecules using plausible generalizations of current theories of magnetic resonance relaxation. It is suggested that very considerably increased information about molecular liquids is obtainable from magnetic resonance measurements by such a study of each chemical type of proton within a molecule, when present.

Perturbation theory in finite nuclei. By J. da Providencia.

In the surface region of a nucleus the nucleon density is lower than in the interior, and it might be expected that this will reduce the effect of the Pauli principle in suppressing correlations. Since in light nuclei the surface region is more important, one expects perturbation theory to work less well, and correlations to be more important, than in uniform nuclear matter.

Calculations with a simple model for O^{16} show that the second-order correction to the energy is almost exactly the same as for uniform nuclear matter, but that two-body correlations are indeed enhanced considerably.

Selective pressure broadening of Si and F spectral lines. By M. B. K. Sarma.

The behaviour of the Si I, II, III and IV and F II and III spectral lines in highly condensed discharges in the range 2900-6000 A.U. at pressures varying from 3mm to 35cm is given. The lines originating from the higher energy levels are found to be more sensitive to pressure.

Improvements in the lattice model of a liquid. By H. N. V. Temperley.

A new type of approximation is introduced, with the objects of examining further the transition of a fluid of non-attracting rigid molecules, and of improving the lattice model of a liquid by reducing the ratio of mesh size to molecular volume. The approximation is first checked by applying it to some simple two-dimensional lattices, reproducing many known results and predicting some new ones. The probable qualitative behaviour of the isotherm of a two-dimensional fluid of rigid non-attracting molecules is determined, available evidence suggesting the existence of a finite region in which the fluid phase is metastable. Some preliminary results on the effect of reducing the lattice mesh size suggest that simple lattice models of a liquid do give physically sensible results in spite of their crudity.

A revision of Kellermann's calculations of the specific heats of sodium chloride. By B. Dayal and B. B. Tripathi.

In the well known work on the lattice vibrations and the specific heats of sodium chloride, Kellermann has not assigned a correct statistical weight to several frequencies and has, further, omitted one point of the Brillouin zone. His results have, therefore, been revised to take these factors into account.

Spin-lattice relaxation times in ruby at 34·6 kMc/s. By J. H. Pace, D. F. Sampson, and Dr. J. S. Thorp.

Measurements of spin-lattice relaxation time in ruby have been made at 34·6 kMc/s by a pulse saturation method at temperatures from 1·4°K to 90°K. With weak concentrations the values for the first order transitions (e.g. 22 milliseconds at 4·2°K) are of the same order of magnitude as those reported at lower frequencies, and the variation of relaxation time with temperature is in fair agreement with theory. A successive increase in relaxation time with the order of the transition, pronounced at 1·4°K, decreases with increasing temperature, and above about 77°K a common value of about 44 microseconds is obtained for all transitions. The main effects of increasing concentration are to reduce the relaxation time and alter its temperature dependence.

RESEARCH NOTES AND LETTERS TO THE EDITOR

Quadrupole-quadrupole interaction in the rare earths. By B. Bleaney. (Research Note.)

The Hartree energies of the helium sequence. By M. Cohen and A. Dalgarno. (Research Note.)

The energy transferred in inelastic ion-atom collisions. By J. B. Hasted. (Research Note.)

The identification of precipitate particles in single crystals of silicon by reflection electron diffraction. By R. C. Newman. (Research Note.)

The elastic scattering of ^{3}He by C, Mg, Al and Cu. By G. Parry, H. D. Scott and S. Swierszczewski. (Research Note.)

An approximate method for the calculation of multipole polarizabilities of atoms. By A. L. Stewart. (Research Note.)

The lifetime of the He^- ion. By D. R. Sweetman. (Research Note.)

The optical absorption of gallium arsenide in the reststrahlen band. By S. J. Fray, F. A. Johnson, J. E. Quarrington and N. Williams. (Letter.)

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UNIVERSITY OF THE WITWATERSRAND, JOHANNESBURG

LECTURER IN DEPARTMENT OF PHYSICS

Applications are invited for appointment to the above post. Duties to be assumed on January 1, 1961, or as soon as possible thereafter. The salary will be according to the scale £1,230 × £60–£1,710. A commencing salary above the minimum notch may be paid on the grounds of special qualifications or experience. In addition, the University is at present authorized to pay an annual vacation savings bonus of up to £60 in September each year. Membership of the University Institutions Provident Fund is compulsory, and membership of the University Staff Medical Aid Fund is compulsory in the case of an officer who is found eligible in terms of the rules. Intending applicants are advised to obtain a copy of the Information Sheet relating to this vacancy from the Secretary, Association of Universities of the British Commonwealth, 36 Gordon Square, London, W.C.1. Applications close, in South Africa and London, on November 30, 1960.

THE UNIVERSITY OF LEEDS

DEPARTMENT OF INORGANIC AND STRUCTURAL CHEMISTRY

RESEARCH ASSISTANT FOR ELECTRONIC COMPUTING

Applications are invited from men or women with qualifications in mathematics, physics or chemistry for a post as research assistant in the Department of Inorganic and Structural Chemistry. The assistant is required to help in the development of programmes for crystal structure analysis on the University Pegasus computer, and will join a team with considerable experience in carrying out very extensive calculations. Previous experience of electronic computing (or crystallography) is desirable but not essential. Opportunities for research would arise in the course of the work. For a well-qualified candidate the initial salary will be £750 per annum with F.S.S.U. Applications should be sent within two weeks to Dr. D. W. J. Cruickshank, School of Chemistry, The University, Leeds, 2.

ROYAL TECHNICAL COLLEGE SALFORD

ELECTRICAL ENGINEERING DEPARTMENT

Due to continued expansion of this College of Advanced Technology, a limited number of vacancies exist for staff at all levels from ASSISTANT LECTURER TO READER. Salaries range from £700 to £2,100 p.a., or possibly higher in exceptional cases. Applicants should be pursuing active careers as electrical engineers or physicists. Considerable importance will be attached to proven ability in research, and commencing salaries will be commensurate with past achievement. Lecturing hours, and equipment available, are such that a genuine opportunity exists for original work. Certain posts are primarily research appointments. Further particulars and forms of application are available from the Registrar, Royal Technical College, Salford 5, Lancs. (please quote ref. B.I.P.), to whom applications should be returned as soon as possible.

UNIVERSITY OF READING

J. J. THOMSON PHYSICAL LABORATORY

Vacancies exist for honours graduate physicists to work on radiation damage effects in solids. The Department is equipped with a 2 MeV electron accelerator which is being used entirely for this work. There is also a vacancy for a physicist to carry out research in the field of electron diffraction. Applicants should preferably have had two years' research experience but this is not essential. Opportunities exist for reading for higher degrees. The salary will depend on experience. Applications should be submitted to Professor R. W. Ditchburn, J. J. Thomson Physical Laboratory, Whiteknights Park, Reading, Berks.

ANOTHER OPPORTUNITY IN IRON AND STEEL

B.I.S.R.A.

SENIOR PHYSICIST. A new post is being established, which will have special attractions for a creative scientist in his late twenties, seeking a real opportunity to prove his skill in research. His responsibilities will include guiding long-range research on the deformation of metals and keeping abreast of developments in this and allied areas of science, with reference to future developments in steel manufacture. The field of research which he himself will be expected to develop touches on high-pressure physics, shock-wave and other dynamic phenomena in metals. Location of post is in the British Iron and Steel Research Association's laboratories at Sheffield, with visits to research establishments here and abroad, as required. Starting salary depending on qualifications and experience, but not less than £1,350. The post is superannuated under the F.S.S.U. Written applications only quoting "M.W.21" to the Personnel Officer, B.I.S.R.A., 11 Park Lane, London, W.1.

UNIVERSITY OF READING

Applications are invited for a LECTURESHIP in AGRICULTURAL ENGINEERING from persons with qualifications in electrical engineering or electronics with an interest in the application to agricultural operations of electronic and other control methods. Further particulars may be obtained from the Registrar (Room 22, O.R.B.), The University, Reading, to whom applications should be sent not later than January 21, 1961.

COURSES

BRADFORD INSTITUTE OF TECHNOLOGY DEPARTMENT OF CHEMICAL TECHNOLOGY

A special short course on

"APPLICATIONS OF NUCLEAR MAGNETIC RESONANCE SPECTROSCOPY"

will be held on Friday, January 27 and Saturday, January 28, 1961. Further details can be obtained from the Registrar, Bradford Institute of Technology, Bradford, 7.

UNIVERSITY OF LONDON

UNIVERSITY EXTENSION RESIDENTIAL WEEKEND COURSE

SCIENCE AND THE STATE

at Moor Park College, near Farnham, Surrey—Friday evening December 2–Sunday afternoon, December 4, 1960. Topics will include: the survival of "pure" Science; the deployment of resources; training and education, the presentation of science to non-scientists; the scientist as a citizen, etc. Discussion will play a large part. Papers will be presented by: R. N. Quirk, Under Secretary, Office of the Minister for Science; Professor G. O. Jones, Queen Mary College; F. Greenaway, Science Museum; H. G. Frost, University Extension Lecturer. Inclusive fee £2 12s. Particulars and application forms from: The Deputy Director (Extension), Department of Extra-Mural Studies, Senate House, W.C.1.

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